THESIS FOR THE DOCTORATE

AN

EXPERIMENTAL INVESTIGATION

OF THE

BOOK METHOD LECTURE METHOD and EXPERIMENT METHOD

OF

TEACHING ELEMENTARY SCIENCE

IN

ELEMENTARY SCHOOLS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

NEW YORK UNIVERSITY

BY

JACOB EDWARD MAYMAN

AT

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APRIL 15, 1912

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FOREWORD

This monograph, as the author states in his preface, is a part of a Thesis which he wrote as a student in the Graduate School of New York University, and which was accepted by the Faculty of that School in partial fulfillment of the requirements for the degree of Doctor of Philosophy. The Thesis was prepared under the immediate direction of the professors of the School of Pedagogy who are also members of the Faculty of the Graduate School in the Department of Education.

The monograph forms an important contribution to the solution of the question of Method in the teaching of Science, or Nature Study, in the elementary schools, and will be welcomed by scientific students of this subject as well as by practical teachers. As will be seen, experimental results do not at all points agree with views at present widely held by teachers of science. That the method of teaching science must differ somewhat according to the maturity and advancement of the pupil is to-day generally recognized; and we no longer attempt to imitate in our best secondary schools the method of the college, nor in our best elementary schools the method of the secondary school. But what more precisely the difference should be, is still largely a matter of empirical study and observation. It is a question which must be determined by scientific experiment, supplemented by experience in the classroom. The author of this monograph has attacked this problem, it seems to me, with considerable success, and his results, even where they cannot be accepted as final, will at least stimulate further experimental investigation.

Thomas M. Balliet, Ph. D.,
Professor of the Science of Education.

New York University,
New York, *June* 8, 1915.

AUTHOR'S PREFACE

After a long and tedious struggle, elementary science (physics) has succeeded in establishing itself in comparatively few cities of the United States. Though the tendency to force elementary physics into the elementary school curriculum appeared early, the question of a proper method or methods of teaching it is of rather recent origin. Many were, and still are, the arguments in favor of this or that method. Pious opinions, based on personal experience, narrow or broad, reigned supreme. The method was adopted or rejected without any serious endeavor to justify such action by scientific facts. As a result many methods, and many more combinations of methods sprung into existence.

In spite of a large variety of methods, the teaching of elementary physics was far from successful. It is the disappointing results, more than anything else, that finally led us to suspect that something was wrong somewhere. The preparation of teachers, the course of study, college influence, and methods of teaching, were, each in turn, scrutinized, investigated, and discussed. The result of all this is: (1) the calibre of physics teachers has greatly improved and is still improving; (2) the influence of higher institutions directly upon the high school, and indirectly upon the elementary school is rapidly waning; (3) courses of study are continually being revised. But the problem of method remains still unsolved.

Of late, many leading educators addressed themselves particularly to this problem of method and attacked it from many different angles. Extended discussions followed; manifold recommendations and suggestions were made. Finally the real remedy was proposed—Experimental Investigation. It stands to reason that definite and positive conclusions regarding the method of teaching elementary science can best be reached only through scientific investigation and experimentation. With this in view, the present investigation was conducted.

The material included in the following pages is an abridgment of a large MS of about 400 pages, submitted in partial fulfillment for the doctorate at New York University in 1912. In the process of editing parts of the original had to be rewritten. Several sections and chapters, and more than half of the original experiments were necessarily omitted. However, great care was taken to give a coherent and unified presentation, even though only *type* experiments are included. The original MS is on file in the library of the University and may be consulted by those who are sufficiently interested.

My acknowledgments for aid are so numerous that they can not, perforce, be made here. I can not close, however, without expressing my sincere thanks and grateful appreciation to Professor PAUL R. RADOSAVLJEVICH of New York University, under whose inspiration and guidance the original Thesis was prepared, and to Director ALBERT SHIELS for making the publication of this brochure possible.

J. E. M.

NEW YORK UNIVERSITY,
NEW YORK, *June* 1, 1915.

CRITICAL SURVEY

It is an incident worthy of note that the development of method in science teaching followed, rather closely the introduction of the subject matter. Science teaching was established only after (a) general dissatisfaction with the prevailing curricula was manifested; (b) persistent agitation in its behalf was carried on by scientists and progressive educators; (c) general adoption of courses of study in elementary science was essayed by progressive communities; (d) these courses of study were imitated. So it is with the method, or rather the various methods, of teaching elementary physics. At first there was no semblance of method. If there was any it was either borrowed from other subjects or it depended entirely upon the whim and fancy of the teacher.[I] This state of affairs produced dissatisfaction and evoked protest and condemnation. As a result attention was directed more and more to the method of teaching. This, in turn, produced several well-defined methods in various quarters. These were generously imitated without any *Whys?* and *Wherefores?* Even to-day, there seem to be no definite, scientific reasons for adopting this or that method. There are no scientific and experimental investigations that help us to choose the best method or methods of teaching elementary science.

That there is unrest and dissatisfaction with science work in our elementary schools is very apparent.[II] But the real source of the trouble is known to comparatively few. A. Some blame the course of study and the nature of the scientific material pre-

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I. "When progress enough had been made in science to win for it recognition as one of the elements of an education it was imparted by the method employed in the teaching of the humanities and there was no distinctive method of science teaching."—Murbach, L.—Method in Science Teaching—School Science, Vol. II—1902. P. 13.

II. "Every experienced teacher, whatever may have been his method, knows from the examination of papers handed to him that the majority of pupils have profited but little, and he washes his hands from responsibility by attributing the failure to willfulness, stupidity or some defect in the students, seeing they did not respond as they should have done to a right method. . . . Something is radically wrong, when after a generation of science teaching, those who have had the best available teaching in it do not show some of the superority, which is claimed for it in insight, skill, tact, judgment and affairs in general."—Dolbear, A. E.—The Disappointing Results of Science Teaching—Ed. Rev. 8:485:1894.

sented to the children. B. Others are dissatisfied with the calibre of the teachers. C. Still others are beginning to question the usefulness and efficiency of the various methods of instruction. No doubt all of these three factors are instrumental in blocking the path of progress in elementary science teaching. But this they do not all do to the same extent and degree. In the subsequent treatment of this matter an attempt will be made to discover, if possible, the role that each of these three factors plays in the teaching of elementary physics or elementary science.

A. Subject Matter in Science Teaching

The introduction of elementary science did not proceed very far when dissatisfaction with the subject matter was generally expressed. (1) One source of discontent was the disproportionate distribution of emphasis and time. (2) One element sought, and is still seeking, to reduce the amount of quantitative work to a minimum, and to bring the qualitative side to the foreground. (3) Some argued that elementary science should be taught somewhat like nature study; whereas others declared themselves for system and logical rigidity in elementary science. (4) Still others deprecated the influence of colleges and universities on curricula in elementary science.—All of these forces of constructive criticism were directed by able men, some of whom were interested in elementary science as teachers, and others as educators.

(1) Prof. John Dewey would have us place emphasis on the method of acquiring scientific knowledge rather than on the knowledge itself. To him "the method demanded by the study is the source of efficiency rather than anything inherent in the content." He states:

> "Science has been taught too much as an accumulation of ready-made material with which students are to be made familiar, not enough as a method of thinking, an attitude of mind, after the pattern of which mental habits are to be transformed."[1]

Prof. Charles E. Barr endorses this in the most emphatic terms:

> ". . . the highest aim is not to teach science. This is an end undoubtedly valuable in itself, but the true purpose of nature study is

1. Dewey, John—Science as Subject-Matter an as a Method—Sci. 31:122: 1910.

broader and deeper. Nature study is a study in correct method of thought. . . . The science that is taught should be, as I conceive it, an incident, the method the end."[1]

With this view J. H. Bradley agrees thoroughly: "What we want to give is rather scientific training than a mass of facts to be remembered."[2]

There are many who agree that the disciplinary value of science teaching is greater than the knowledge that is to be acquired. On the other hand, there are many more, who are strongly opposed to this view. Prof. E. L. Thorndike sums up the situation as follows:

"It became fashionable to assign a relatively small value to acquaintance with the facts and laws of science, and to direct teaching to habits of accuracy in observing and recording phenomena. As a consequence courses were occasionally designed which were nearly as barren of any important knowledge as the traditional exercises of the first year Latin book. Wires were measured whose length meant nothing of consequence to any one; thermometers were read for no purpose except to read them; trivial details of animal structure were painfully examined and elaborately drawn for observation's sake alone."[3]

That habits of observation and verification can be fostered by the study of elementary science is not denied. But the majority of thinkers on this subject make this of secondary importance. Greater emphasis should be laid on the kind and amount of actual knowledge to be acquired and the number of every-day applications.

(2) This quarrel is lost sight of in the larger one between those who defend quantitative, and those who strongly urge qualitative work, in elementary science. Those who defend the quantitative aspect of elementary science teaching are small in number but persistent in their demands. The views of these "strict constructionists" in elementary science are ably represented by W. S. Franklin and H. R. Perkins.

"Physics, next to mathematics," says Perkins, "is the most exact science in the sense that there are known to physics, more fundamental

1. Barr, Chas. E.—Nature Study—Jour. of Ped. 15:114:1903.
2. Bradley, J. H.—The Place of Science in the Schools—in Broad Lines in Science Teaching by F. Hodson—P. 13.
3. Thorndike, E. L.—N. Y. State Ed. Dept. Bul. 34, 1907—P. 70.

laws capable of exact mathematical expression than to any other science. . . . In teaching such subject, then, one can not lay too much stress on the underlying principles, the law behind the experiment, that the experiment is only intended to illustrate."[1]

Similarly, W. S. Franklin says:

"Nothing indeed is so essential in the acquirement of solid knowledge of physical things as the possession of precise ideas; not because a perfect precision is necessary or even helpful as a means of retaining knowledge, but that nothing else so effectively opens the mind to the perception even of the simplest evidences of a subject."[2]

The opposition (those who strongly advocate qualitative instead of quantitative work in elementary science) has grown from a small and insignificant minority to a large and compelling majority. Among its leaders are included such men as Prof. Mann of Chicago University, Prof. Hodge of Clarke University, and Prof. Woodhull of Columbia University. These gentlemen have spread their gospel far and wide, both through their written and spoken word and have made hundreds of converts.[I] But small space can be given here to the expression of their views:

Prof. C. R. Mann—"Abstract and difficult concepts in the form of definitions and laws are thrust upon the student without warning and before his mind is adequately prepared for them by suitable common sense discussions of his concrete experiences—he does not feel their necessity or see their use."[3]

Prof. C. F. Hodge—"What we need is a quality of knowledge which shall be alive and set the child's face right towards the universe, and thus form the foundation for active, helpful living." Again, ". . . scientific analysis is a fundamental process, but for elementary work the revolt against it is universal."[4]

Prof. John F. Woodhull would have us learn a lesson from the old-time writers of elementary science. He illustrates his point by a practical example. In discussing Wells' book "Natural Philosophy" he says:

I. Of the seventy-two informants in the Bureau of Education, Circular of Information, No. 7—1884, sixty-six have expressed themselves in favor of qualitative work in elementary science teaching. All over the country now Science Teachers Associations have been formed in order to make a proper study of this important problem.

1. Perkins, H. R.—The Teaching of Science in the Schools—Sch. Sci. and Math. 5:694:1905.
2. Franklin, W. S.—Physics from the College Point of View—Ed. Rev. Jan. 1911—P. 85.
3. Mann, C. R.—The Physics Teachers Problem—Sci. 29:957:1909.
4. Hodge, C. F.—Foundations of Nature Study—Ped. Sem. 7:100-103:1900.

"Hollow bones of animals, hollow stalks of grains, and hollow columns of buildings are discussed among other interesting things. Within the last fifteen or twenty years, however, the exigencies of college preparation have substituted for all this a laboratory exercise in which the pupil attempts to find the number of grams required to break a piece of small wire. We certainly need common sense instruction about strength of material. . . . The fact that it requires a pull of a certain number of grams to break a piece of No. 24 brass wire is of no concern to any of us—not even to the bridge builder. It would seem that laboratory teachers, like kindergarten folks, have been at much pains to invent 'busy work'."[1]

That the labors of those who advocate qualitative, practical work in elementary science is bearing fruit, is evident in the revision of the courses of study that is continually being effected all over the country. Instead of the abstract law or principle about the co-efficient of expansion of various metals we study the thermostat in our school room. The study of gas meters, fountain pens, inflated basket balls, etc., replaces the abstruse scientific data regarding the pressure of gases. The study of the school heating and ventilating plants is to be substituted for carefully-planned, sugar-coated experiments in the class room.

(3) There is still another source of contention: Shall elementary science be taught as a logically, systematized subject? Shall it be taught as a part of nature study, incidentally, and in the form of interesting talks and observations? or, Shall it be taught in such manner as to combine these two elements? The first question is answered in the affirmative by several writers and a few of the courses of study that were examined. "A vast advance is made in profitable teaching," says Barnett, "if the pupil is induced to recognize the validity of the same logical laws, classification, definition, proof as well as the need of logical precision in every subject of investigation."[2] This idea is reiterated by Stearns, who says, "In lower schools teach with simplicity and *exactness* the elements of natural philosophy and chemistry, with special application to 'things familiar'."[3]

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1. Woodhull, John F.—The Teaching of Physical Science—Teachers College Record, Vol. XI, Jan. 1910—P. 5.
2. Barnett, P. A.—Common Sense in Education and in Teaching—P. 243.
3. Bur. of Ed. Circ. of Inf. No. 7—1884—P. 24.

A large majority, especially those who hardly make any distinction between natural philosophy and nature study, answer the second question positively. The following quotations are typical:

Mowry, Wm. A.—"I do not think it desirable to introduce physics in lower schools as a regular study with text books. Much general information can be given by any skillful teacher, but if it were taught as a regular branch it would be, I think, to the serious detriment of the elementary and essential branches."[1]

Wright, D. S.—"I do not think it desirable to introduce formal instruction in physics in the lower schools. The instruction should be merely incidental, oral, and without books."[2]

Cornish, R. H.—"This simple, non-mathematical observaticnal method of studying physics is, it seems to me, a part of nature study, and appropriate to grades below the high school."[3]

A much saner view, which is also the increasingly prevailing view, is taken by those who strike a happy compromise. Sir Oliver Lodge puts this idea in the following words: "Science is best taught and best assimilated in the nascent stage. . . its special aroma is lost if it is imparted as a thoroughly understood and organized system alone, though that too is, of course, one aspect of it."[4]

There are several reasons why this should be so:

a. Elementary science covers a large field and therefore must be spread over several grades.

b. If each grade is to cover a portion of the whole field, certain definite divisions—entirely topical—need be made.

c. Logical arrangement of subject matter obviates confusion in the minds of teacher and pupil.

d. Moderate systemization enables the teacher to arrange her lessons in the order of their difficulty or according to any other consideration.

e. There must be a definite progression in teaching and in learning which will keep the interest of both teacher and pupil.

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1. Bur. of Ed. Circ. of Inf. No. 7—1884—P. 44.
2. Bur. of Ed. Circ. of Inf. No. 7—1884—P. 29.
3. Cornish, R. H.—Matter and Method in Physics Teaching—Sch. Sci. 2: 333:1902.
4. Lodge, Sir Oliver—School Teaching and School Reform—P. 108.

f. Wherever the departmental plan of teaching is used, correlation with other subjects and with the same subject in other grades can not be carried out unless there is definiteness and orderly arrangement.

g. Unless the teacher has carefully planned her work excursions and tours can not be arranged in advance and for that reason can not be undertaken at all.

h. No small advantage is derived from a saving of time and effort through order and system.

i. In places where several schools are grouped under a responsible supervisor or other official, frequent examinations are given. Unless there be moderate uniformity throughout all of the schools in the group, such examinations will be impossible.

Any arrangement, course of study, or systematized and detailed plan which does not conserve the freedom, spontaneity and initiative of the teacher is faulty. Therefore, in planning a course in elementary science, the teacher should be consulted, either in person, or through a representative committee. The plan must be elastic enough to give the teacher free reign in enriching, deepening, and broadening the subject. Ultra-systematization is as bad as, or worse than, no systemization. A compromise must be effected if teacher and pupil are to gain something from the work in elementary science.

(4) The influence of colleges and higher institutions of learning in elementary science teaching is still complained of. The upper grades of the secondary schools and the academies have more reason to complain than the elementary schools; although the same influence is felt here indirectly. H. L. Terry puts all the short-comings in the elementary science work (particularly in the high schools) at the door of college influence. "The college specialists' influence, acting through college entrance requirements and through text books prepared in accordance with these requirements, dominates the teaching of physics in our secondary schools to-day."[1]

1. Terry, H. L.—The New Movement in Physics Teaching—Ed. Rev. 37: 13:1909.

B. The Teacher and Science Teaching[I]

The more the teaching profression "relizes" itself, the more it seeks to improve teaching conditions, the more and more it calls for highly trained men and women to enter its ranks. But a highly trained college man or woman does not necessarily make a good and sympathetic teacher. We are just beginning to realize the truth of this statement. Progressive boards of education and superintendents are no longer satisfied with a mere college education. They require, in addition, "some training" in the art and science of pedagogy. This requirement, though it is still not what progressive teachers would prefer, is very significant and points to a broader, saner, and more professional development. The need of men and women of sound scholarship who are well versed in the art and science of education is sorely felt. The long-felt complaint regarding the lack of properly qualified teachers is ably expressed by Dean Thomas M. Balliet:

> "Now, my contention is that the graduate instruction in our universities does virtually nothing to fit a teacher to teach either science or mathematics in a vital way in secondary schools. It may even be possible that the highly specialized training of the graduate school, to a certain extent, unfits the student to do this sort of teaching. However that may be, I state a well-known fact when I say that not one in fifty of the men and women who take the Doctor's degree in science or mathematics has the least conception of the problem before him when he begins teaching in a secondary school. . . .
>
> "The highly specialized training of the best graduate schools seems to make it difficult for the young teacher to view his work from the standpoint of his pupils rather than from the standpoint of the subject."[1]

Speaking of the preparation required for good physics teaching, Prof. E. H. Hall makes a half-hearted plea for thorough training in the art and science of pedagogy.[2] He frankly confesses his full share of the "prejudice created against 'methods'." In the second place, he holds that a student who has received a conscious instruction in physics has also received an unconscious instruction

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I. *"The real and most vital problem now is that of getting teachers who are competent to teach sciences effectively."*—Mann, C. R.—The Meaning of the Movement for the Reform of Science Teaching—Ed. Rev. 34:17:1907.

1. Balliet, T. M.—The Influence of the Present Methods of Graduate Instruction on the Teaching in Secondary Schools—Sch. Rev. 16:219-21 & 22:1908.

2. Smith & Hall—The Teaching of Chemistry and Physics in Secondary Schools—Pp. 245-46.

in the art of teaching. Thirdly, he has some apprehension lest a study of the philosophy and psychology of the art of teaching will lead the prospective teacher to give less attention to physics than to the teaching of it.

However, Prof. Hall has no pronounced objection to such preparation:

> "The opportunity of beginning one's teaching in a moderate way, under the supervision of an experienced teacher and frank critic, before taking the full and permanent responsibility of conducting a class, is an opportunity to be desired. If in divinity schools there is a place and use for courses in 'Homiletics and Pastoral Care,' it is difficult to see why in the nature of things, there should not come to be in the formal training of the teacher a place and use for courses dealing with the technicalities of his art as such. I observe, however, that, in the catalog from which I have taken the heading quoted above, this heading is placed over the very last division, except elocution, of the courses of instruction open to students of divinity. The learning, the science, stands foremost; then comes the art. Thus should it be in the training of the teacher."

Because the book of which Prof. Hall is joint author has been, for a long time, the only one of its kind; because of the constant agitation of all great educators for thorough professional preparation of teachers in whatever line; and because of the guiding principles revealed by the new experimental pedagogy, the author should have taken a distinctly positive stand in urging and demanding thorough scientific training in the art and science of teaching, for prospective physics teachers.

C. Methods of Teaching Elementary Science

As was stated above, dissatisfaction with the results in science teaching has been expressed by many progressive educators. For a long time the objects of attack were the courses of study and the teachers; but of late more and more attention and criticism is brought to bear on the method of teaching this important subject. Not that courses of study and teachers are now considered perfect, but because experimental pedagogy and teachers' general professional awakening, have revealed new lines of investigation and experimentation which lead to the improvement of methodology in all subjects.

In elementary science, as in other subjects there are several methods of teaching. Each of these has ardent supporters and advocates as well as relentless opponents. Some use this, some that, and some the other method. Others use a combination of two, three, and more of these methods. Still others recommend a variation of method. The consideration of each of the following methods will now engage our attention:[1]

I. EXPERIMENT METHOD
II. LABORATORY METHOD
III. QUESTION AND ANSWER METHOD
IV. EXCURSION METHOD
V. OBJECT METHOD
VI. OBSERVATION METHOD
VII. BOOK METHOD
VIII. HEURISTIC METHOD
IX. LECTURE METHOD
X. VARIATION METHOD

I. THE EXPERIMENT METHOD

As its name implies, the experiment method, is the method which makes use of experimental demonstration, by the teacher, in imparting a lesson.

This method implies many other things which need not necessarily be mentioned in a description of it. For instance, the manner of approach, induction, deduction, observation, application to every-day life, etc., etc. If the lesson be on the ***pendulum*** one teacher might "prepare the child's mind" by an interesting talk on clocks, in which both teacher and pupils participate. This may create interest in, and give reasons for the experiment. Another teacher simply states the object or the purpose of the experiment, and proceeds. The experiment itself—the bare pro-

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I. This classification, while true to a great extent is more or less arbitrary. It has been attempted for one purpose only—clearness. As far as I know, there is only one other similar classification. It is the one Prof. Hodge worked out in connection with nature study. A summary of it is here given for the sake of comparison and completeness:—1. Book Method; 2. Logical Method; 3. Scientific Method; 4. Aesthetic Method; 5. Museum Method; 6. Dr. Wilson's Myth-poetic Method; 7. The Sugar-coated-pill Method; 8. Excursion Method; 9. Knothole Method; and 10. The Active Method which is recommended by Prof. Hodge himself.[1]

1. Hodge, C. F.—Foundations of Nature Study—Ped. Sem. Vol. VII. 1900—Pp. 208-228.

cess—is neither inductive nor deductive. The lesson itself may be either, or both. Again the matter of observation and application to daily experiences are only adjuncts to the experiment. All of these factors are dealt with, more or less, in a lesson that is taught experimentally. And this lesson may be extended over one or more periods, depending entirely upon the teacher and the exigencies of the occasion. But the purpose here, is to disregard all of these factors—necessary as they may be—and to consider the method of the experiment *per se.*

In order to carry out the experiment successfully, the teacher must spend a good deal of time in preparation. Assuming that the apparatus—either bought or made—is at hand, he must first "set it up" and then go through the experiment himself, in order to make sure of everything, and to save himself possible mental discomfiture in the presence of his class. Every experienced teacher knows that this must be done with every piece of usable apparatus at least once a term, every term.

Everything having been set in readiness *beforehand,* the teacher is prepared to demonstrate.[1] After a more or less brief description of the apparatus, the teacher performs the experiment from beginning to end. While he is doing this, he also explains the various steps. If everything goes well and the demonstration is plain, he usually says nothing. If, however, the operation is lengthy and involves several steps, he may engage the pupils' interest by asking questions. These questions are calculated either to draw explanations of, and reasons for, the various steps, or to call up related old knowledge of previous experiments. This, however, is not part and parcel of the experiment and is no necessary requirement of this particular method. In fact, most of the time the pupils do nothing but observe—intelligently, it is supposed.

It must be understood that the mere experiment does not constitute the "lesson-whole." Further discussion, explanation, questioning, problem-solving, writing up of notes, reference to supplementary reading, application and illustration may follow. But

1. In most cases the class is seated in ordinary seats, those in front having the advantage over those in the rear, (or vice vera, considered from their point of view). In some cases the pupils are allowed to stand around the teacher's demonstration table or desk.

all of this is not peculiar to the experiment method. It may be done in conjunction with any other method. It depends entirely upon the teacher and not upon the experiment. If we are to judge the value of any method, we must strip it of the attributes that are common to all methods.[I]

The experiment method is used in the public schools of New York City as well as in some other cities where elementary science is taught. It has many advocates. Among these may be mentioned L. C. Miall, Balfour Stewart, and I. J. Osbun.

Miall, L. C.—"I suppose that every one, will, if possible, give experimental physics a good place in the school course. It is so informing and so stimulating, gives such abundant opening for observation, reflection, and construction, that it can not be passed over without serious loss."[1]

Stewart, Balfour.—"These experiments must be performed by the teacher in regular order before the class. The power of observation in the pupils will thus be awakened and strengthened and the amount of accuracy of knowledge gained must be tested and increased by a thorough system of questioning."[2]

Osbun, I. J.—"Natural philosophy is pre-eminently an objective science. From its nature it demands to be taught by the objective method.[II] Nearly all its phenomena are to be presented by experiment."[3]

The advantages claimed for the experiment method are:[III]

1. The children like it.
2. It is concrete. (Things, not words.)
3. It trains the senses.
4. The powers of observation are aroused and strengthened.

I. This will be the attitude in all later discussion of the various methods .

II. This must not be confused with the "object method" or the "object-lesson."

III. The advantages and disadvantages given here are expressions of various authors. They are given, with the conscious understanding, that they are, in most cases, mere expressions of opinion or limited class room experiences. In other words, these expressions are not, or were not derived from experimental investigation. Further, it is not my intention to question the validity of these expressions at this point. This will be done later. The sole object, at present, is to give an unbiased setting to each method.

1. Miall, L. C.—The Teaching of Science—in Teaching and organizations by P. A. Barnett—P. 251.
2. Stewart, Balfour—Physics—Introduction.
3. Osbun, I. J.—American Institute of Instruction, 1881—P. 179.

5. An interest in experimentation is fostered.
6. The memory is indelibly impressed.
7. It furnishes the mind with permanent possession.
8. The child gets direct information.
9. Accurate knowledge is gained.

This seems almost like an invincible argument for the use of the experiment method. But there are those who are not so optimistic. Speaking of the object and experiment method, Prof. Chas. A. McMurry says that they are "the most highly recommended and the least successfully practised phase of instruction." Continuing he says, "This is but one illustration of the wide breach between enthusiastic theory and successful practise."[1] This is a general indictment of the method. There are, however, more specific statements relating to the disadvantages of the experiment method:

1. Too much of the teacher's time is taken up in the preparation.

2. The apparatus, whether bought or made, has a money value. In most cases it is bought. This involves a burdensome expense.

3. The teacher does all the work. The children merely observe.

4. The apparatus is a source of distraction.

5. Children remember the apparatus and not what is intended to be taught by means of it.

6. The experiment is apt to be considered as an amusement.

7. "An experiment modifies the conditions of nature in such a way as to show what are the essential phenomena. . . . A great difficulty is in getting the students to see clearly the difference between the results of the modified conditions and the conclusions that can be drawn from such results."[2]

8. Modified conditions of experiments are outside of the pale of the child's experiences.

All of the reasons, pro and con, are in themselves sufficient to prove that the experiment method can not be accepted or rejected

1. McMurry, Chas A.—Special Method in El. Sci.—P. 83.
2. Murbach, L.—Method in Science Teaching—Sch. Sci. 2:16:1902.

without further examination and scientific proof. In other words, we can not properly judge this method unless we have certain definite, scientifically determined standards which we can apply. Have we such standards? The answer to this question is very definitely given by Prof. W. C. Bagley: "What we lack primarily in educational science, then, is a series of standards by which the growth that pupils make in the realization of our educational ideals may be adequately measured,—."[1] As far as can be ascertained, no one has yet made any experimental or statistical investigation with regard to this or any other method of teaching elementary science.

In the absence of standards that measure true efficiency, a good deal depends upon "pious opinion" and limited personal experience. Opinion is ever ready with "reasons," "facts," and "hypotheses." But for every opinion that is given in favor of a proposition an equally convincing one can be raised against it. All we can do in the present case is to pit the "advantages" against the "disadvantages" of the experiment method and discard from both those that cancel each other, and struggle with the remaining ones. The burden might be reduced by getting rid of the advantages and disadvantages which are not factors of the experiment method alone;—those which might be equally well applied to any other method. Still we have plenty of opinion left on both sides. And if we are to decide on the validity of the method on the basis of what is left, we are obliged to make use of further opinion or authority to justify our decision. Thus we see mere opinion justifying itself by more opinion, and finally ending in mere opinion.

"The need for definite educational standards has been keenly felt for some time. Until the school can measure in an effective way the actual results of its work,—until it can determine with some measure of precision how its processes work out in the lives of its pupils,—the work of teaching will not be able to command the rewards that everyone is willing to admit it deserves."[1]

1. Bagley, W. C.—The Scientific Method in Educational Research—Nature Study Review, 6:173:1910.

"Efficiency in any line of human endeavor depends upon our ability to evaluate the results which are secured."[1]

II. THE LABORATORY METHOD

There is perhaps no method which has had such stormy career as the laboratory method. It had, and still has, its fervent admirers and uncompromising opponents. It is a product of the college and the university which slowly made its way into the secondary school and thence into a few of the elementary schools. It has, therefore, been discussed thousands of times by thousands of men in various walks of life;—college presidents, city school superintendents, manufacturers of apparatus, makers of laboratory manuals, etc., etc. It is readily understood that the mass of opinion expressed by these people is far from unanimous. Some call it the only "ideal" method, and others are content with the appelation of "stuff" and "stunts."

The laboratory method is the method by which the student acquires knowledge through his own experimentation. Individual experimentation involves, among many other things, the placing of apparatus at the disposal of the student. This is not as easy as it might appear at first glance. There are two methods that are commonly used in elementary work. (a) The class method, and (b) the group method.

In the class method each pupil is supplied with the appropriate apparatus. The teacher states the problem (or puts it in the form of a question), gives the "directions" and the children proceed to experiment. This requires one piece, or one set of apparatus for each pupil. Here the question of cost enters in; and too often it is the only determining factor.

Mostly to reduce the cost, and partly to foster the spirit of co-operation and mutual helpfulness, the group method has been introduced. In this case one piece, or one set of apparatus is given to each group of two, three, or four pupils. The problem and directions are given by the teacher, and the group proceeds to experiment on the co-operative plan.

1. Strayer, D. D.—Measuring Results in Education—Jour. of Ed. Psych. 2:3:1911.

Both of these plans have their strong and weak points. The class plan provides for individual laboratory work. But the best of teachers find it difficult to manipulate large classes in the laboratory. The work can not be thoroughly supervised, and too little of the personal influence and attention of the teacher is received by the pupils. On the other hand, the group method makes it somewhat easier for the teacher as an overseer, but its value to the pupils is questionable. Very frequently each group is dominated by one enthusiastic worker whose zeal leads him to perform all of the work while the rest merely look on, or what is worse, pay no attention at all and later "copy results." It must be borne in mind, however, that there are many experiments in elementary physical science which can not be performed by individual students. For this purpose the group method is well adapted. Further, the mutual assistance of individuals in a group is of great sociological, as well as educational value.

In the absence of statistical and experimental investigation with regard to the efficiency of either of these methods, criticism of all kinds may stand. But in reality it is not worth much. What is necessary and pedagogically important, is to try both of these methods under controlled conditions,—as, for instance, time, place, character of teacher and pupils, quantity and quality of work, etc. —in a sufficient number of cases, and with a sufficient number of pupils and to carefully check up results by means of uniform tests. Then, and then only, would we have a proper basis of comparison and criticism.

Whatever the detailed plan of laboratory machinery may be, the purpose of the laboratory method is to engage the self-activity of each child in finding truth by means of the experiment. Psychologically considered, there is no fault to be found with this principle. On the contrary, it might even be endorsed. Pedagogically considered, especially from the point of view of experimental pedagogy, there is more or less uncertainty about it. In fact there is more than uncertainty. There is a long, drawn-out but persistent quarrel between those who idealize the laboratory method, and those who are equally determined that it is unproductive of good results.

Among those who advocate the laboratory method are: Avery, E. M., Avery and Sinnott, Bailey, F. H., Cooley, L. C., Gage, A. P., Garlick, A. H., Huxley, T. H., Hodge, C. F., Mann, C. R., Murbach, L., Shaw, A., Smith, P., Spencer Herbert, Worthington, A. M. This partial list includes those who have had something to do with the instruction in elementary science. In addition, a host of educators, not directly connected with the teaching of elementary science, have expressed themselves in favor of the laboratory method.

A few quotations will indicate, in a general way, the trend of thought.[I]

Avery and Sinnott: "Require each pupil to perform many of the experiments. The more of this work he does, the better for him. The best, *i. e.* the ideal, plan would be for each pupil to have a set of apparatus and a regularly assigned place at the laboratory table. In many schools, this would be impossible, but much may be done at extemporized tables and with such experiments as the teacher and pupils make."[1]

Bailey, F. H.: "In physics thus studied the pupil is fully engaged—hand, head, heart, for he is always interested in experimenting. The physical training in manipulating apparatus that is neither too difficult nor too easy; the mental training in seeing what occurs and in connecting it with the cause, if the experiment is adapted to the mental condition of the pupil, and the moral training in engaging the attention of the entire child in the proper study of those laws under which he 'lives and moves and has his being'—speak so loudly for the laboratory method that we do not believe any true teacher who has ever tried it can be persuaded to adopt any other."[2]

Cooley, L. C.: "It is pleasant to anticipate the time when every common-school shall be provided with an appropriate set of apparatus, through which Nature may teach her simple truths to children in her own playful and child-like manner. . . . The best teachers of natural science are unanimously of the opinion that the very best result can be secured only by allowing the students to make experiments for themselves."[3]

Huxly, T. H.: "But if scientific training is to yield its most eminent results, it must, I repeat, be made practical. . . . in teaching him physics

I. Quotations are taken from such books only as are recommended for elementary school use.

1. Avery and Sinnott—First Lessons in Phys. Sci.—P. 4.
2. Bailey, F. H.—Inductive Elementary Phys. Sci.—Intro.
3. Cooley, L. C.—Easy Expreiments in Psys. Eci.—Pref. IV-V.

and chemistry you must not be solicitous to fill him with information, but you must be careful that what he learns he knows of his own knowledge. Don't be satisfied with telling him that a magnet attracts iron. Let him see that it does; let him feel the pull of the one upon the other for himself."[1]

Murbach, L.: "The laboratory method has given us the most efficient way of learning facts of science, making them a part of our knowledge, instead of parroted wisdom. But experiments (lab.) teach not only facts and principles; they also train, and give power to find new data and laws, and so contribute to human knowledge. It trains in manipulation, observation, reflection, comparison, judgment."[2]

Shaw, A.: "The best plan is to have each pupil perform the experiments as directed in this book, and afterward to let the class witness the same experiments by the teacher."[3]

By this time we have a composite idea of the laboratory method which carries in its wake hope, confidence and cheerful anticipation. But let us look at the reverse side of the same picture. The following quotations are more interesting when their source is considered:

Mann, C. R.: "Thus in the matter of facilities for presenting the subject of physics, substantial progress has been made in the acquisition of the laboratory; but in the matter of knowing how to treat the subject, we have made little progress—many think we have gone backward.

"Somehow most of the students regard the subject matter as so much 'stuff' that has to be gone over, and speak of the laboratory exercise as so many 'stunts' that have to be performed in order to get credit."[4]

"We are beginning to see that the acquisition of laboratories has not by any means solved the problems of science teaching, but that the experiences of the past fifteen years have shown that we do not yet know how to use the laboratories most efficiently."[5]

Hall, E. H.: "It is so difficult to design a course of laboratory experiments which will lead the pupil to discover or observe, in any general way, phenomena not previously known to him, so difficult, therefore, to prevent qualitative laboratory work from becoming a farce and

1. Huxley, T. H.—Science and Education—P. 127.
2. Murbach, L.—Method in Science Teaching—Sch. Sci. 2:13:1902.
3. Shaw, A.—Physics by Experiment—P. 6.
4. Mann, C. R.—Physics Teaching in tne Secondary Schools of America—Sci. 30:794:1909.
5. ——— ———In "Broad Lines in Science Teaching" oy Hodson,—P. 228.

a bore, in which the weary teacher points out to each pupil the thing which the latter is supposed to discover, that I have long considered the undertaking unprofitable."[1]

Cornish, R. H.: "Valuable as I consider the laboratory, it must be confessed that unless very careful supervision is exercised a great deal of time is wasted in so-called laboratory work, and this work is apt to degenerate into play, or from want of direction into aimless, discouraging, and profitless effort on the student's part."[2]

Dewey, John: "A student may acquire laboratory methods as so much stuff, just as he may so acquire material from a text book. One's mental attitude is not necessarily changed just because he engages in certain physical manipulations and handles certain tools and materials. Many a student has acquired a certain dexterity and skill in laboratory methods without its ever occurring to him that they have anythng to do with constructing beliefs that are alone worthy of the little knowledge."[3]

We now have a rather complete view of the laboratory method. Let us summarize:

Advantages of the Laboratory Method

1. The pupil is fully engaged—head, hand, and heart are always exercised.
2. It trains him to hunt for truth independently.
3. It trains the pupil in careful observation and verification.
4. The knowledge gained is concrete and at first hand.
5. It gives a "taste" for further experimentation and discovery.
6. It follows the development of mind—from the simple to the complex, and from the concrete to the abstract.
7. It appeals to the pupils because they like to "do" things.
8. It trains the senses.

Disadvantages of the Laboratory Method

1. Equipment is very costly.
2. Laboratories take up too much floor space.
3. Teachers make "mental drones" of pupils by telling them too much.

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1. Hall and Smith—The Teaching of Chem. and Phys.—Pp. 318-319.
2. Cornish R. H.—Matter and Meth. in Phys. Teach.—Sch. Sci. 2:389:1903.
3. Dewey, J.—Science 31:125:1910.

4. Pupils do not draw proper conclusions.

5. They do things mechanically.

6. A good deal of guess work is involved.

7. When the desired results are not forthcoming, copying is resorted to.

8. Students consider it "stuff" and "stunts."

9. It is difficult to arrange a qualitative set of laboratory exercises which will keep the interest of the students.

10. Too much time is wasted.

11. Too much supervision is required.

12. It is not a natural method—experiments are foreign to child nature.

A very essential element of the laboratory method is the keeping of note-books. This aspect of the work is a bane to the teacher, and a source of disgust to the pupil. Teachers spend laborious hours in 'correcting' note-books which are supposed to indicate the pupils' accomplishments in the laboratory.[1] It is usually required that pupils enter into their note-books a description of the experiment, a statement of the object and result of the experiment, a conclusion and generalization, and a fairly accurate drawing of the apparatus used. While it is true that pupils like to handle apparatus and even to experiment systematically, at times, it is positively certain that the great majority of them hate to "write up" their work. And only the talented ones really like to make the drawings.

The plain fact is that note-book work, as it is usually demanded, is very difficult for elementary school pupils; yes, even for high school pupils. Those who can't do it begin to hate laboratory work on account of it. And those who can, think that success depends, not on rational knowledge based upon laboratory work, but upon a neatly written and amply illustrated note-book. The result is an enormous waste of time and energy in carrying out work which is uninteresting to the teacher, barren of good results to the pupil, and repugnant to both. Yet teachers and supervisors

1. If the books are written in the laboratory, this might be expected. But usually they are not, and what the teacher reads is too often the work of the proverbial collaborator and judicious helper.

seem to be unanimous in their opinion that note-book work is indispensible.

In order to save the teacher's time and energy and to help the pupils in this difficult task, attempts have been made to furnish each pupil with a printed blank for each experiment. All the pupil has to do is to fill in certain spaces and answer questions. This method is now adopted by higher institutions and is imitated with various modifications by secondary and elementary schools. It has not been sufficiently used; if it has, it has not been sufficiently discussed to enable one to form a definite opinion about it. It seems, however, that the greatest drawbacks in printed blanks is that it tends to make machines out of the pupils. It need not take long before the form, arrangement, and general content of the blanks become so familiar that they are disregarded, and the only thing to which the pupil must pay attention is the blank space which *must* be filled in.

Considering all circumstances, the laboratory method of instruction does not come up to the expectations of its advocates. Aside from the disproportionate financial disbursement, it takes up an enormous amount of time and is unproductive of efficient results. Considered from the point of view of psychology and pedagogy, there seems to be nothing wrong with the method itself. The pupils like it. It exercises their self-activity. It arouses their interest and curiosity. It is concrete. It trains the mind through the hand. All of that it does, and more. And yet there is considerable dissatisfaction with it. Its opponents do not say, "Away with it." What, then, is to be done?

Perhaps we could come to a satisfactory solution by admitting, from the start, that the laboratory method is a good method; but it is woefully abused. With this premised, we might take it upon ourselves to try it out under variously controlled conditions and circumstances. Try it with note-books and without note-books; with printed blanks and without; qualitatively and quantitatively; try it with laboratory manuals and without; with diagrams and without; with the group and with the class arrangement; try it with home-made and ready-made apparatus; try it inductively and deductively; try it for long and short periods; try it at various

times of day—in short, "experiment, investigate, and verify." But in all these trials or experimental investigations, sufficient experiments must be made under uniform and controlled conditions. Then the results might be checked up from the point of view of economy and efficiency. We would, then, be in a position to talk more intelligently about the laboratory method.

III. QUESTION AND ANSWER METHOD

Taking the experience of the child as the basis, the teacher asks carefully graded questions and the child is supposed to answer them. The assumption is that the child's experience is wide enough and varied enough; but that it is not organized and classified. It is also assumed that new knowledge can be imparted by combining various elements of the old through the medium of questions. After the lesson is developed (or when the supply of good questions is exhausted) the teacher summarizes by *telling* the principle or law which the questioning is supposed to have brought out. Mrs. L. P. Hopkins is a great believer in this method. The following model lesson is taken from her book, "Practical Pedagogy":

TEACHER—Prescott, yesterday I saw you drawing Dick up Union Street in your cart. Was it as easy for you as to draw him down the hill?

PRESCOTT—No Ma'am; but I had to hold back almost as hard going down.

TEDDY—The cart goes itself down the hill.

TEACHER—Oh, no; something is pulling it down which you don't see. Let go that book in your hand; what made it go down?

WILLIE—It is heavy.

TEACHER—What does heavy mean?

PRESCOTT—Hard to hold up.

TEDDY—It pushes hard.

TEACHER—There is a power of the earth which pulls everything towards it. It is called gravitation. You may all write the word. It makes things seem heavy when they push hard towards the earth, or have much weight.[1]

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1. Hopkins, L. P.—Practical Pedagogy—Pp. 111-12.

While questions and answers are entirely legitimate in the development of any lesson, by any method, to use them as Mrs. Hopkins recommends—as the sole means of teaching a new lesson —will involve prominent faults:

1. In drawing upon the child's experience the teacher is trying to teach what the child already knows.

2. Children's experiences vary, and therefore can not positively be taken as a common basis for the entire class.

3. Children will always give the answer which, in their estimation, will please the teacher; and not the one which ought to be given.

4. The entire procedure is too abstract.

5. It has been found that children lie in order to appear "experienced"—to show that they have seen this or they know that.

On the other hand, the good qualities of the question and answer method must not be overlooked. Its use fosters a closer relationship between teacher and pupil, and between pupil and pupil, through the exchange of common experiences. It teaches the children to see their experiences from a different angle. It developes the imagination to a wonderful degree. It gives rise to a certain frankness of expression which makes for sociability and close companionship.

At its best, the question and answer method can serve only a supplementary purpose. Like the Socratic method, it is good—but not when used alone. In connection with other methods—experiment, laboratory, etc.—it is very valuable both as a guide to the teacher and as a "mental tonic" to the pupil. Its use is very convenient because of the fact that it can be so advantageously employed with other methods.[1]

1. I am committing, here, the usual sin, i. e. Basing conclusions on limited personal experience and on opinions of others. This I am forced to do, because I, personally, did not investigate this method scientifically, nor could I find any such investigation carried out by anybody else.

IV. THE EXCURSION METHOD

This is a method that takes the children out of the school room into the world and actual life to study elementary science. If the subject be *"boiling," "steam-heating,"* or *"ventilation,"* the pupils take a trip to the basement of the school to find out all about it. If it be a lesson on the *steam engine, dynamo,* or *motor,* the children are taken to the places where these are found. This method is recommended in connection with other methods that the teacher may use. But F. A. Vogt lays especial emphasis on it. He calls it the "Buffalo Plan" and claims for it the following advantages:

1. It counteracts the indifference of parents.
2. It leads the young mind back to a simple and more humanizing condition of life.
3. It trains in habits of correct observation.
4. The child sees life in its environment.
5. The child acquires specific information not contained in books.
6. It gives children a good time.

All this is very true and the method should be encouraged. But it has serious difficulties to encounter. Some of these are:

1. Large classes.
2. Teachers do not care to give their time after school hours.
3. Teachers hesitate to undertake the responsibility for accidents that might occur.
4. Lack of co-operation on the part of owners of machinery and other objects for observation.
5. Many children can not afford the time after school.
6. Children get a vague impression of complicated machinery and do not really learn much.
7. The difficulties of the course of study can not very well be graded.
8. It consumes a great deal of time.
9. Excursions can not be enforced upon pupils who refuse to participate.

1. Vogt, F. A.—Outdoor Science in Secondary Schools—Sch. Sci. 1:109-18: 1901.

In spite of these difficulties occasional excursions can be successfully conducted. It will be most fruitful when it shows practical applications, or illustrations of the knowledge gained in the class room. The pupils get the necessary "finish" to their theoretical and very often unintelligible work in the school. Like the question and answer method it is very good and can be profitably used in connection with one or more other methods, but not as the sole avenue of instruction.

V. THE OBJECT METHOD

As the name implies, elementary science is taught by means of objects. Whatever lesson is planned it is based upon the observation of one or more objects brought to the room either through the efforts of the teacher or the pupils.

Let us suppose that the lesson is on the *"lift pump."* According to the dictates of this method, either the teacher or the pupils bring to the class room a model or a real lift pump. At first, the teacher carefully examines it in the presence of the class so that they will, in turn, know for what to look and how to examine it. Then the pump is handled, in turn, by each pupil who looks at it as the teacher directs, or because he has to answer a definite question which calls for a particular observation. Very often, lack of time does not permit of individual handling of the object. In this case the class is divided into small groups and each group makes the necessary observation. Sometimes a representative committee makes a report on their observations and the rest of the class merely listen. Whatever the shortcomings, in practise, are, in theory, at any rate, the object is supposed to be examined and carefully observed by each pupil.

After the object has completed its circuit, a general discussion or written report of the observation may follow. But this is not a part of the method itself, and a discussion of it is out of place here. It is of interest, nevertheless, to read the "Directions for the Teaching of Science in the Primary and Grammar Schools" of Middletown, Connecticut:

> "The teaching should be chiefly objective. Large, well-defined pictures may be used whenever it is impossible to obtain real objects. . . . All

classification should, so far as possible, be the result of observation and comparison, on the part of the pupils. Let the teacher stimulate, direct and name. Happy the teacher, and fortunate the pupils, if, in this delightful work, the teacher judiciously combines speech and silence. An occasional talk, however, by the teacher, on the subject before the class, is both proper and desirable. Such talks should furnish information beyond the reach of the pupils' observation.

"Every lesson should be carefully prepared. Aimless and irrelevant conversations are profitless. Allow and encourage the freest expression of what the pupils see. *Encourage the pupils to collect and bring in specimens. Elicit, by judicious questions, a description of what they have brought. Give them additional observation. If necessary, postpone the subject till the next day, and learn something about it.*"[1]

The earliest exponent of the object method was J. A. Comenius, and it is from him that the enthusiasts gained their inspiration. In his chapter on the teaching of science, he recommends that "Everything should, as far as possible, be placed before the senses. Everything visible should be brought before the organ of sight, everything audible, before the hearing. Odors should be placed before the sense of smell, and things that are tastable and tangible, before the sense of taste and touch respectfully. If an object can make an impression on several senses at once, it should be brought into contact with several. . . ."[2]

To show to what extent his disciples are influenced in their advocacy of the object method, the following quotation is given:

"Method of the Object-Lesson:—The object should be exhibited . . . for the inspection of the class; and the qualities important to be noticed should be observed by the appropriate senses. The action of the several senses is not to be interchanged, thus, a quality cognizable by touch alone such as hardness, is not to be vouched for by the sight, but verified by the sense of touch.

". . . there is no stereotyped plan for an object-lesson or any other lesson; but that the teacher should, by following certain principles, select that plan which seems to him best suited for the exposition of the lesson in hand."[3]

The object method, as well as the observation method, was very prominent in the eighties, when the Pestalozzian movement

1. Rice, Wm. M.—Science Teaching in the Schools—Appendix II.
2. Keatinge, M. W.—The Great Didactic of Comenius—Pp. 336-37.
3. Currie, James—The Principles and Practice of Common-School Education—Pp. 381-382.

was at its height. It was part of the general movement in opposition to book learning. If properly used, it has many virtues:

1. It is concrete and practical.
2. It arouses and satisfies the curiosity of the pupils.
3. It is a complete thing that the pupils learn, and not separate parts, facts or laws that require constant explanation from the teacher. They see the thing in its entirety before them.
4. It appeals to the "handling instinct" of boys.
5. It aims to train all of the senses.

On the other hand, it easily lends itself to misuse which was so prevalent in the early eighties. Then, again, seeing a thing is not seeing it "work". And this is exactly what nearly every boy, at least, is interested in. From the point of view of class room management, this method offers serious obstacles. In a class of forty, it takes a long time for an object to "go the rounds."[I] This leaves a portion of the class always idle. No matter what the teacher may do, if she preserves the unity of her class, this condition is inevitable. Still, a good deal can be accomplished with this method of teaching.

VI. THE OBSERVATION METHOD

The observation method is an immediate development of the object method. In point of time, it is hard to draw the distinction between them. It may be said that they were coexistent. But the observation method was used by the teachers at various times after they, or their superiors, were dissatisfied with the object method.

For a time the distinction between the two methods was not apparent and the names of both were synonymous.[II] But there is a distinction between the two. In a broad sense, and to a limited degree, they are similar because they are both based on *observation*. The distinction is that in the object method, observation

I. In case of large objects which the class, as a whole, observe, or where there are duplicate objects, this criticism is untenable.

II. In fact, John T. Prince has a chapter in his book—Courses and Methods—entitled "Observation Lessons" under which he discusses the *object*-lesson.

is directed toward isolated things, while in the observation method, it is directed to things in their natural environment. In the first, the observation is minute and detailed, and in the second it is extended and general. The former seeks to convey information through the exercise of all of the senses, if possible; the latter employs mostly the sense of sight. The one brings the facts to the child; the other brings the child to the facts.

The observation method is very extensively used in Nature Study proper because of its adaptibility to that study. When it is used in connection with the physical sciences, it often takes the form of an excursion. A great many observation lessons can be given in the science room, *i. e.*, an environment can be created in the class room. This is very easily done in electrical work. In so far as the observation method does not involve a trip outside of the regular class room it is different from the excursion method.

The observation method or the method (according to nature) was vitalized by Pestalozzi,[I] and more practically applied by the great body of his admirers in the teaching profession. Winchel calls this the most "rational method". Its aim "is to bring the child into contact with the facts, and leave his own mind, as far as possible, to draw the general inferences to which the facts point. . . . His own faculties are then active, and to some extent, in all cases, the principles reached are principles discovered; the child feels a consciousness of success—a pride in it, an exhilaration over it, and the whole exercise is a delight."[1] It must be added here that Dr. Winchell expects the pupil to reach general-

I. "All science-teaching that is dictated, explained, analyzed, by men who have not learned to think and to *speak in accordance with the laws of Nature;* all science-teaching of which the definitions are forced as if by magic into the minds of children like a *Deus ex Machina,* or rather are blown into their ears as by a stage-prompter,—so far as it does this it must necessarily sink into a miserable burlesque of education . . .

"There are and can be no *two good* methods of instruction in this respect. There is but *one*—and this is the one that rests entirely upon the eternal laws of Nature. But of *bad* ones there are *infinitely many;* and the badness of every one *increases* in proportion as it *deviates from the laws of Nature,* and *decreases* in proportion as it *approaches* to following these laws."—Holland and Turner—Trans. of "How Gertrude Teaches Her Children"—Pp. 243-44.

1. Winchell, A.—Thoughts on Science Teaching—Reprint from "Fortnightly Index,"—July 12th, 1884—Pp. 10 and 15.

izations through a "ratiocinative process." If the pupil be incapable, generalizations must be given dogmatically.[I]

In addition to what Pestalozzi and Winchell claim for the method, Murbach says that it is the easiest to follow.[1] The method as it is described, ought to work out well with elementary school pupils. It has, however, about the same disadvantages that were stated on page 32 with regard to the Excursion Method. Here again, one is not on safe ground when he attempts, in the absence of scientific facts, to "rate" the method.

VII. THE BOOK METHOD

The earliest method used in the teaching of elementary science is the book method.[II] In its early form it consisted merely of getting the bare thought from the printed page.[III] To-day, books on physics are a good deal more than a collection of printed pages. The modern book contains clear pictures, cuts and diagrams, maps and charts. It contains actual photographs of men and things in daily life. The type and arrangement of material is both very convenient and artistic. Most books contain printed directions for individual experimentation whenever practicable. In short, the modern physics book aims to combine as many methods as possible in presenting the subject matter to the pupil.

I. "There must be sometimes a descriptive statement of facts. There must be a dogmatic delivery of inductive doctrines. There must be, unless we would have our teaching grossly defective, a frequent dogmatic exposition of the necessary consequences of established principles."—Winchell, A.—Thoughts on Science Teaching—Reprint from "Fortnightly Index," July 12th, 1884—P. 8.

II. In 1886, Harvard demanded laboratory work as an essential requirement that its students in the freshman class had to fulfill. Previous to this date, book knowledge was sufficient.

III. "There is a strong tendency in this age, which has seen and is daily seeing science decending from her heights, to diffuse her instructions among those of the most humble walks of life,—to adopt the most easy, indeed, but not therefore the best method, of bringing her teaching and their capacities to an equality. Instead of raising them to her level, or rather striving to bring them as near it as may be, she is brought down to theirs, and bidden to lay aside her depth, and the exactness of her speech, that she may talk to them, as nurses do to infants. Books which strip science of its difficulties, are commended, as if its difficulties were extraneous matters, which ought to be removed,—a sort of artificial barricade, which the learned had devised merely for the purpose of securing their own privileges and immunities from vulgar intrusion, and which the unlearned have a most republican right to war against as they please."—Hale, Benj.—On the Best Mode of Teaching Natural Philosophy—American Institute of Instruction, 1833—Pp. 298-99.

1. Murbach, L.—Method in Science Teaching—Sch. Sci. 2:12-18:1902.

The Object and Observation methods are represented by clear cuts and diagrams. The Question and Answer method is fully employed by appending at the end of each chapter, or at the end of the book, some very searching and practical questions. The printed directions as to experimental procedure very often leads boys to do a great deal of laboratory work at home. Then comes the subject matter itself, which, if written in a clear and simple style, is very interesting to the pupils.

Considering all this, the Book Method of to-day is not really a simple method; but a concoction of several. To study the merits or deficiencies of the Book method alone, it is obvious that we must discard all the accessories which are not native to it. However, we must not be too severe in the exclusion of simple and clear diagrams. This is premised, not because the modern book is considered inferior, but because it is too all-embracing. And to criticize it in its entirety would be to criticize several methods at once.

The development of the Book method in this country is very interesting. At first books were written with a view to explaining every-day phenomena. When the laboratory craze set in during the seventies and early eighties, more and more space was given to principles or laws of physics than to daily occurrences and facts relating to science. The books were written with a view to co-operating with, and supplementing the work of the laboratory.[I]

To-day, while the cry for laboratory work is still persistent, there seems to be a tendency to return to the old-fashioned books.[II] The authors of these books invariably recommend the use of their books in connection with some other method—usually with the laboratory or experiment method. But the aim of all is to treat in a very elementary manner, of the application of scientific

I. "Physics should not be made a means of teaching mathematics. I have, therefore, substituted experimental problems for the *mathematical problems* which are *usually* given in treatise on natural philosophy, in the hope of cultivating the scientific instinct."—Trowbridge—The New Physics—Pref. Pp. IX and X.

II. "Elementary Physical Science" by Prof. Woodhull, is an example. He calls it "a book to aid the teacher, to correlate the experimental work with the experiences in the daily lives of the pupils and with the other subjects of the grade." Some of the subjects treated are "City Water System," "City Gas System," The Atmosphere of New York City," "Steam Heating," "Hot-Water Heating," etc.

principles to life, and of every-day appliances in the arts. Of late, such books have become popular.

The Book method, minus its modern adjuncts, like any of the other methods, has its advantages and disadvantages. In the following quotation, Prof. O. W. Caldwell very ably summarizes the benefits of the text book recitation:

"The recitation, when solely from one text book, is often conclusive and 'settles things', and possibly sounds better to some pupils, teachers and visitors, than do recitations into which are injected the various reports of pupils who have observed varying phenomena. To both teachers and pupils it often gives greater immediate satisfaction to study and recite solely from books. The assignment has definitely set limits, and the pupil feels that he knows when he has prepared all his lesson. He may come to the class with a feeling of certainty that he has compassed the materials assigned to him."[1]

But farther on in the same article we find this qualifying statement:

"The learning and reciting of lessons from text-books is necessarily an essential part of school work, but becomes most profitable when properly related to experience other than that had with the text-book."[2]

Steele, in his "Fourteen Weeks", says: "Students are expected to obtain information from this book, without the aid of questions, as they must always do in their general reading. . . . He should *never be allowed to answer a question,* except it be a short definition, *in the language of the book.* The diagrams and illustrations, as far as possible, should be drawn upon the black board and explained. Although pupils may, at first, manifest an unwillingness to do this, yet in a little time it will become an interesting feature of the recitation."[3] The author does not make this assertion without foundation. All of this has been tried "in his own class." And yet in the next paragraph, he says: "It should be constantly borne in mind that, as far as possible, *every question and principle should be submitted to Nature for a direct answer by means of an experiment.*" His book also contains very many questions and diagrams.

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1. Caldwell, O. W.—The Text-book and Nothing More—Sch. Sci. and Math. 5:582:1905.
2. Ibid, 5:583:1905.
3. Steele, J. D.—Fourteen Weeks in Physics—P. IX.

The outcries against the Book method of teaching are as old and as numerous as those against "book knowledge." (The distinction between the two is seldom made.)

Norton, Wm. H.—"Science teaching is objective. Its impressions are at first hand, it brings us face to face with facts. How weak and vague, how illusory and fleeting is the impression of the work compared with that of the thing. It is our peculiar privilege to teach things, not words. . . . The Text-book teaching of science is so markedly inferior to the laboratory method that it is fast disappearing from the schools."[1]

Shaw, E. R.—"The author concludes from his own experiences and from that of a great number of teachers with whom he has consulted, that, as a rule, text-books upon physics are too difficult for beginners."[2]

Huxley, Thomas H.—"If scientific education is to be dealt with as mere book work, it will be better not to attempt it, but to stick to the Latin Grammar, which makes no pretense to be anything but book work."[3]

The Book method is one of the methods which has been investigated. Further comment at this point is neither desirable nor profitable.

VIII. THE HEURISTIC METHOD

The names Heuristic Method and Henry E. Armstrong are almost synonymous. No method had, or has, such vigorous and persistent exponent as the Heuristic Method has in Henry E. Armstrong. In reality, this method is nothing more nor less than the laboratory method of teaching elementary science or any other subject. It is treated here as a separate method because (a) it is an outcry against prevailing laboratory methods as well as other methods, and because (b) of its unusual emphasis upon the self-activity of the pupil. The requirements for accuracy of perception, calculation and observation and strictness in the manipulation of apparatus, though not unusual, are very strongly emphasized. Books and laboratory manuals are discarded entirely. The pupil writes his own book as he progresses in his career as "discoverer," "inventor," and "problem solver."

1. Norton, Wm. H.—The Teaching of Science—Sch. Sci. 2:195:1902.
2. Shaw, E. R.—Physics by Experiment—P. 4.
3. Huxley, T. H.—Science and Education—P. 125.

Two or three paragraphs from Prof. Armstrong's book will give us some idea of the Heuristic Method:

"Heuristic methods of teaching are methods which involve our placing students as far as possible in the attitude of the discoverer—methods which involve their *finding out,* instead of being merely told about things.[1]

". . . the didactic instruction which poisons our existence at the present day will be properly recognized as a fell disease.[2]

"It is in no sense mere opinion on my part, but a conviction gradually forced upon me and established beyond all doubt by actual trial and observation during many years past, that the beginner not only may but must be put absolutely in the position of an original discoverer; and all who study the question particularly are coming to the same opnion, I find. Young children are delighted to be so regarded, to be told that they are to act as a band of young detectives.[3]

"It is of no use for the teacher merely to follow an imaginary research path; the object must ever be to train children to work out problems themselves, and to acquire the utmost facility in doing so. Of course, the problems must be carefully graduated to the powers of the scholars and they must be insensibly led; but do not let us spoil them by telling them definitely in advance what to look for and how to look for it; such action is simply criminal."[4]

In contravention, it might be averred that the attitude of discoverer is not the right one for a beginner in elementary science. Young pupils can not follow a research path. The object of each experiment must be made plain to them. The teacher must direct them as to what and how they should observe. They can not draw conclusions from their own experiments. Pupils must first acquire a moderate amount of scientific knowledge in order to be able to "reason out" their experimental data and calculations.

To these objections Dr. Armstrong retorts: "—a couple of earnest men, without preconceived views but full of common sense, in the course of a half a dozen years succeeded in applying it (the method) to a large number of scholars in public elementary schools, which surely are sufficiently difficult and unpromising material to deal with."[5]

1. Armstrong, H. E.—The Teaching of Scientific Method—P. 236.
2. Ibid—P. 238.
3. Ibid—P. 253.
4. Ibid—P. 254.
5. Ibid—P. 260.

IX. THE LECTURE METHOD

This method is more familiarly known as "oral lessons", or just "talks". It was used a good deal before object and observation lessons were popular. It is used to-day where experimental apparatus, books, or primers of some sort, are not available.

The teacher either reads up, or calls upon her experience, narrow or broad, for the subject-matter of the lesson. In the presence of her class, she starts the lesson in a conversational manner. It is supposed that the pupils join in the conversation and with the skillful aid of the teacher, come into full possession of scientific truth. But how can children participate in conversation for which they have no apperceptive basis or experience to buoy them up? In a case like this, the children would rather hear the teacher talk. And she does talk most of the time. In other words, she gives them an informal lecture. She may occasionally, make use of diagrams on the black board, or of pictures on the wall. The entire work devolves upon her. The children are interested, all of the time—either in the lecture or in something else.

The oral method, as it should be, is well described by Farrar. But in practice, it really resolves itself into a very elementary lecture. In part, he says:

> ". . . the master who is teaching a class quite unfamiliar with the scientific method, ought to make his class teach themselves, by thinking out the subject of the lecture with them, taking up their suggestions and illustrations, criticizing them, hunting them down, and proving a suggestion barren or an illustration inapt; starting them on a fresh scent when they are at fault, reminding them of some familiar fact that they overlooked, and so eliciting out of the chaos of vague notions that are afloat in the matter in hand, be it the laws of motion, the evaporation of water, ..."[1]

The darker side of the same picture is portrayed by H. R. Perkins:

> "In many elementary courses no text-book is used, and the lecture system is followed. This may give satisfactory results in some subjects, but in physics it can not be too severely condemned. In order to train

1. Farrar.—A Liberal Education—Pp. 381-2.

the student to think, he must be compelled to work for himself, and though the lecturer may give references and advise study, those who have tried it know how hard it is to exact the outside work so necessary in a mathematical course like physics, and the ability to wrestle with a difficult problem or concept is not fostered by what may be termed the 'kindergarten method' in science."[1]

Further discussion is reserved for a later section in which experimental results are given.

X. THE VARIATIONAL METHOD

This is a method without method. We have seen the strong and weak points of the various methods, discussed above. Some have discovered the plan of varying the methods of presentation on different occasions. In this way they are able to fit the method to the lesson and not the lesson to the method as is so often disastrously done. One such lesson comes to mind now. The lesson on the electrophorus, whenever presented by the purely experimental, or purely laboratory method, results in a flat failure. But when there is freedom of choice among all of the methods, there is, at least, the possibility of trying one after the other until the right one is found.

With variation of methods great lattitude must be given to the teacher, and the wise teacher will turn this to great advantage. One method of presentation will do for a bright, cheerful morning; but another must be mustered into play on a dull, rainy afternoon. At times it is imperative to *tell;* sometimes it is urgent to *discover.* Time, or lack of time, is sometimes a very important factor. A wise choice of method will suit both. In short, if freedom, lattitude and initiative are allowed, the teacher will make the eventual choice which will produce the best results—best from the point of view of efficiency and economy. But what is to guide her in her choice, other than the personal equation or numerous trials and errors? These are all very uneconomical for both teacher and pupils. Up to the present there has been no attempt to answer this question scientifically.

1. Perkins, H. R.—The Teaching of Science in Schools—Sch. Sci. and Math. 5:696:1905.

It might be assumed that nearly all of the numerous admirers and advocates of the several methods mentioned, will admit the advisability of variation in method. But a careful search for a tangible expression of this proved fruitless. William T. Harris is the only one who has clearly, boldly, emphatically put this idea in such form that it can not be mistaken. Here is a quotation:

> "Whereas, in ordinary lessons the pupil is required to be so intensely active that he can not sustain the exertion for more than thirty minutes, in the natural science lesson he is to give his attention for one hour. . . . but the teacher is to vary the lesson by lecture, experiment, reading interesting descriptions, conversation with the pupils about their experience, that the class shall be able to do this without excessive fatigue."[1]

SOME COMBINATIONS OF METHODS

A discussion of the ten methods can not be called complete unless some mention is made, at least, of a few of the recommended combinations that are possible by joining two or more methods together. The combination of methods in the imparting of a lesson in physics is the rule rather than the exception. But we can not possibly understand any combination if we are ignorant of its component elements. We will first mention the combinations recommended by Jackman and by McMurry. These are especially recommended for use in elementary schools and are, presumably, based on experience.

The combination of methods urged by Wilbur S. Jackman is:

1. Direct *observation* which "may call into play any or all of the senses, touch, sight, hearing, taste, smell, and the muscular sense."

2. The second step is the use of *pictures* or *models* which symbolize, partly or wholly, the real objects.

3. Pure symbols, *i.e., hearing* or *reading language.*

4. "*Making* is the most definite and complete mode of expression, where material representation is possible."

5. *Modelling* is another form of expression which the pupil should employ.

1. Harris, Wm. T.—How to Teach Natural Science—P. 14.

6. *"Painting* as a mode of expression is unique."

7. "In science, *drawing* may be employed with great advantage in all subjects."

8. "Rationally employed, *written expression* is the most valuable adjunct in science work."

Here we have a combination whose elements are numerous indeed. But it must be understood that several of them are not used at all in the teaching of the lesson proper. They are used in the lesson-whole which includes illustration, application, generalization, etc. In the words of Mr. Jackman, "Each mode of expression is peculiar in this, that it has a special function of its own which can not be perfectly performed by any other one or more modes, though of course they do supplement each other in almost every expression of thought."

McMurry,[1] not to be outdone, has given us the following compound of methods: (1) observation, (2) experiment, (3) laboratory, (4) object (collections), (5) question and answer (problems), (6) book (reference books), (7) lecture (on topics beyond the reach of children), (8) excursion, (9) pictures and diagrams, (10) note books.

Here we have nearly all of the methods brought together without reserve. It may be said that the child will surely learn something when all of these are employed. But is there any regard for time and efficiency? Have these methods been tried out singly and in combination, and as a result this conglomeration found to be the best? If we say that each of these methods is to be used where they will be most effective, we are probably expressing Prof. McMurry's views correctly. But how will the teacher know which method will be effective on any one particular occasion? Is she to accept the theories of one or two teachers who claim to talk "from experience"? Or is she to imitate a teacher who has tried *one* method and found it satisfactory? It is patent that she should do neither. Modern educational thought and practise are now trying to abandon, entirely if possible such procedure. The researches in the modern pedagogical laboratory and clinics blaze forth the path which we must follow. "Opinion"

1. McMurry, Chas. S.—Special Method in Elementary Science—Pp. 82-126.

may count for something; "experience" for a little more; but both must yield to the positive, scientific results obtained from thorough statistical and experimental investigations.

The combinations recommended by Jackman and by McMurry are by no means the only ones in the field. It is easily seen that the ten methods, discussed above, may be combined by two's and three's, etc., thus making more than one hundred combinations possible. It is useless to discuss many more of these combinations because the characteristic elements of each individual method have already been mentioned. The five combination methods discussed below are chosen because they are commonly used in elementary schools. The sixth one is mentioned, not only because it is used in some quarters, but also because of its eminent source.

(a) Experiment and Book Method

In addition to the experiment the lesson is reinforced by reading matter from an appropriate book—usually a text book. The book is used either for home study or class room reading.[I] To meet the objection raised against the use of a text book with elementary school pupils, attempts have been made to compile interesting "natural science readers," or "books of information" which deal mostly with applications of class room experiments. Such books are not as numerous to-day as they were forty or fifty years ago. Books of this nature, dealing with modern appliances and every-day illustrations of scientific principles would probably be as interesting to the children, and as prolific of good results as the modern geographical reader.[II]

(b) The Experiment-Laboratory-Book Method

This method is advocated by LeRoy C. Cooley, and is described by him as follows:

". . . the following plan ought to prevail in presenting elementary facts. An easy experiment or some phenomenon of common occurrence,

I. "The intention is that the teachers shall first perform the experiment prescribed for a given topic, with such inductive work as may be necessary, and afterwards assign the appropriate lesson from this Book of Information."*

II. The experiment-book method is advocated by Joseph Landon also. In addtiion, he urges the use of objects, and in the absence of these, the use of pictures to be observed by children."†

* Woodhull, J. F.—El. Phys. Sci. for Gram. Grades—Pref. VI.

† Landon, J.—The Principles and Practice of Teaching and Class-Management—P. 442.

is to be introduced and the attention of the child directed to certain appearances and conditions, after which he may be called upon to notice the truth which these appearances suggest. A concise and accurate statement of the fact or principle itself, in form to be easily remembered, may finally complete the investigation.

"Many of the experiments are such as the pupils can make for themselves; let them be encouraged to do so; if they are, they will soon be bringing to the notice of the teacher, others which the text does not describe."[1]

(c) Experiment and Home-Laboratory Method

This is an ingenious method which avoids the expenditure of money for duplicate sets of apparatus, and at the same time gives training in laboratory work. To this end Charles L. Harrington has written a novel little book[2] which directs and guides the pupil through his experiments at home. The apparatus consists of various utensils usually found in the home and of simply "constructed" pieces. Such things as glass tubing, pulleys, sealing wax, etc., the pupil is advised to buy. Whenever considerable expenditure of money is involved, or when money may be saved by buying at wholesale, the advice is that "pupils should club together."

The method in detail is as follows: "The experiment set for the students should be performed at home, and notes of his observations should be written on slips of paper. During the recitation periods the results obtained by the several students should be compared and criticized, and the correct results then and there written in the blank spaces left for the purpose in this book. The experiments performed by the teacher should be closely observed by the students, and *they* should state the correct results."[3]

(d) Experiment-Excursion Method

This method is recommended by J. R. Sypher and by G. Compayre. With regard to the excursions, Sypher says: "If there are

1. Cooley, L. C.—Natural Philosophy for Common and High Schools—Pp. 6-7.
2. Harrington, Chas. L.—Physics for Grammar Schools—
3. Harrington, Chas. L.—Physics for Grammar Schools—Pref.

any manufacturing establishments in the vicinity of the school house, the teacher should take his pupils thither and explain the mechanical forces employed in the operations carried on there."[1]

Compayre takes a different view: "Nothing is more helpful to the teaching of science than scientific excursions. But it must not be forgotten to preserve their character of recreation and diversion. The instruction that is given in them should take place in the presence of pupils in the form of familiar conversations, and the instructor should not carry outside of the class room the habits and the didactic method of the school."[2]

(e) The Experiment-Empirical Method

This method is recommended by N. A. Calkins: "Facts relating to philosophy and science should be presented to children first through experiments. When the range of possibilities in school room work has been reached in this direction, other important facts, to supply further knowledge of the subject as a whole, may be taught *empirically,* especially when the pupil's lack of knowledge in other kindred departments of science prevents his knowing these important and needed facts through other means."[3]

(f) The Experiment-Historical-Newspaper Method

This is not an uncommon combination among modern teachers. To those who use it, it is gratifying to know that it is endorsed by such high authority as Sir Oliver Lodge. "Now, in a progressive subject like physics," says he, "there is always a tract of it conspicuously in the throws of development. Some inklings of it get into the daily press. . . . This adventitious and popular interest should be made use of as a stimulant, and employed so as to encourage at any rate some percentage of youth to settle down to serious study, so as to understand some of these things, not superficially, but more substantially.

"But there is another mode of obtaining science in a nascent stage, viz., the historical mode, pointing out some of the steps which in the past led to discovery, and not give the full blown

1. Sypher, J. R.—The Art of Teaching School—P. 257.
2. Compayré, G.—Lectures on Pedagogy—Pp. 395-96.
3. Calkins, N. A.—Manual of Object Teaching—P. 338.

results apart from the earlier and less coherent steps which led to it."[1]

In the Circulars of Information[2] of the United States Bureau of Education, for 1880 and 1884, we have, among other things one hundred and nineteen (119) individual expressions regarding methods of teaching physics in the elementary schools. Let us classify these opinions in the light of our discussion of the various methods:

	The Methods	No. who prefer it.
I.	Experiment Method	13
II.	Laboratory Method	0
III.	Question and Answer Method	1
IV.	Excursion Method	0
V.	Object Method	3
VI.	Observation Method	2
VII.	Book Method	11
VIII.	Heuristic Method	0
IX.	Lecture Method	17
X.	Variational Method[3]	1
	Combinations	
a.	Experiment and Book Method	9
b.	Experiment—Laboratory—Book Method	1
c.	Experiment—Home Laboratory Method	1
d.	Experiment—Excursion Method	0
e.	Experiment—Empirical Method	0
f.	Experiment—Historical—Newspaper Method	0
	Other Combinations	
g.	Experiment—Observation Method	1
h.	Object-Book Method	1
i.	Experiment—Book—Lecture Method	2
j.	Experiment—Lecture Method	6
k.	Book and ? Method	2
l.	Lecture and Book Method	1
m.	Object—Book Method	2
	Method not stated	14
	Physics not taught or recommended	31
	Total	119

1. Lodge, Sir Oliver—School Teaching and School Reform—Pp. 109-10.
2. Circular of Information, United States Bureau of Education, No. 6, 1880—A Report on the Teaching of Chemistry and Physics in the United States—Clarke, F. W.
1. Circular of Information, United States Bureau of Education, No. 7, 1884—Aims and Methods of Teaching Physics—Wead, Chas. K.
3. Encloses Dr. Harris's Syllabus.

This table shows that the three most popular methods, in the order of their standing, are, (1) the Lecture Method, or (oral method); (2) the Experiment Method; and (3) the Book Method. It is interesting to note that the Laboratory, Excursion, and Heuristic Methods received no votes. This is explained by the fact that they are comparatively new.

Can we draw conclusions as to the efficiency or inefficiency of a method from these figures and from the preceding discussion of the various methods? Certainly not. On the contrary, all of this shows glaring disagreement and nothing is scientifically determined. Confusion in methods of teaching physics is paramount. Progressive educators realize this and protest.

In this connection Dean Balliet says:

> "Now the natural sciences are intrinsically interesting to pupils of the secondary school age if well taught; and when they are not, the teaching is at fault."[1]

M. F. Guyer says that the "question as to proper material is not so distressing to the teacher as the problem method."[2]

Prof. C. R. Mann puts the matter very bluntly, thus:

> "The chief reason for the present failure of the physics course, to train in scientific thinking seems to me to lie in the fact that the method of presentation used is thoroughly unscientific."[3]

In another place he says:

> "But if we examine . .. the statistics of the school, and note how science is avoided when there is free election, we must conclude that the fault lies with the science instruction rather than with the schools."[4]

For a long time (and even to-day) people have attributed the shortcomings of physics teaching to this, that, and the other thing. It did not occur to them that the question of method in physics teaching might be scientifically investigated and its faults exposed and remedied, if possible. Now we are beginning to understand

1. Balliet, T. M.—The Influence of Present Methods of Graduate Instruction on the Teaching in Secondary Schools—School Review, 16:220:1908.
2. Guyer, M. F.—The Question of Method in Nature Study—Ped. Sem. 12:86:1905.
3. Mann, C. R.—The Physics Teacher's Problem—Sci. 29:957:1909.
4. ——— ———Sci. in Civ. and Sci. in Ed.—Sch. Rev. 14:665:96.

that the manner of presentation of any subject is as important as, if not more important, than any other single influence or circumstance. It took us a long time to locate the difficulty. This in itself is an accomplishment of no small value. Now that we have discovered the source of the evil, what are we to do with it? The answer can easily be found in the new science of education—Experimental Pedagogy. What this new science has done, and is doing for spelling, reading, writing, arithmetic, etc., it can also do for elementary physics.

Here again, Prof. Mann points to a solution of the problem. "Progress," says he, "depends on our applying to our teaching problems the methods of our subject." In the same article he suggests the use of experimentation by saying: "Another (scientific experiment) would consist in presenting the same topic to several different classes by different methods to see if some previously unintelligible topics might be made intelligible if differently treated."[1]

This is the best and only solution of the method problem in elementary physics as well as in other subjects. The original suggestion of Prof. Mann, made in 1909, is reinforced later in the same year (Nov.) by the Central Association of Science and Mathematics Teachers; in 1910, by Prof. W. C. Bagley; and in 1911, by Prof. F. L. Holtz.

In its report on the "relation of elementary school nature-study to secondary school science" the special committee of the Central Association makes the following as one of its five recommendations:

> "To stimulate extensive experimentation in teaching Nature-Study in the grades, to the end that scientific data upon the question may be collected."[2]

"The sources of human motive may be hard to discover," says Prof. Bagley, "but the outcome of human motive is a very real thing. How much the processes of education contribute to this outcome and how much must be attributed to inherited

1. Mann, C. R.—Physics Teaching in the Secondary Schools of America—Sci. 30:796:1909.
2. The report is printed in "Nature Study Review," January, 1910.

traits and congenital variations, we are unable now to say. But if, in a series of closely observed and carefully controlled cases, a repeated variation in the educative process continually produces a concomitant variation of the conduct-outcome, we may be fairly confident that the teaching stands to the conduct-outcome as cause to effect—although through what series of intervening links we may be quite unable to say."[1]

Prof. F. L. Holtz is in full accord with this view: "It should be possible to make some comparative study of the method of eliciting and the method of direct instruction. The problem is a complex one, but it would be worth while discovering whether the book method is as black as it is painted or the development method in the hands of the average teacher any better."[2]

We have now placed our finger not only upon the fundamental cause of failure in elementary physics teaching, but also on the remedy.

Careful and controlled experimentation with all of the methods, and with combinations of methods, would be very instructive. But the usual limitations of opportunity, material, expertness, time, etc., make such ideal unattainable under ordinary circumstances. Therefore it was decided to experiment only with the three most popular methods—Lecture, Book, and Experiment—and, to a limited extent with one combination of methods.

EXPERIMENTAL INVESTIGATION

The Problem

"The study of method in teaching is but the study of the best way of doing what must be done in some way." In order to help us in "the best way of doing what must be done," the "old school" recommends the study of psychology, logic, philosophy, child-study, etc. Above all, a thorough familiarity with the "Guide-Posts" or "principles" of Education is indispensible.

1. Bagley, W. C.—The Scientific Method in Educational Research—Nature Study Review—6:174-75:1910.
2. Holtz, F. L.—Pedagogical Problems in Nature Study—Jour. of Ed. Psych. —2:566:1911.

Posts, indeed, they are. But they point nowhere! They do not guide! The bewildered teacher is amazed to find that the inscriptions thereon become unintelligible and finally vanish as soon as he makes a serious attempt to read them. His faith in them is shaken.

Ultimately, these time-honored "posts" must fall. They have neither the firm foundation, nor the strength of material, to weather the storm that the newer scientific education is raising. Biased and personal opinion must and will make room for impartial, scientific facts. If education, in general, and methodology, in particular, is to hold its own among the rapidly developing sciences, it must adopt the dignity, the spirit and the method of these sciences.[2]

What is the *best* way of teaching elementary science (physics)? The present experimental investigation seeks to answer the question, but not completely. To this end, four methods were investigated, *i.e.,* (1) The Book Method, (2) The Lecture Method, (3) The Experiment Method, (4) The Experiment-Note-book (Combination) Method.* Our problem, thus limited, is, then: Which one, or more, of these four methods is the best, from the point of view of efficiency, economy, interest, permanency, etc., for the purpose of teaching elementary science (physics) to elementary school pupils? In order to answer this question intelligently, scientifically, and definitely, if possible, I have undertaken to teach the subject of elementary science (physics) *by each one of these methods* to fourteen classes in one of the public elementary schools of The City of New York.

1. Greenwood, J. M.—Principles of Education Practically Applied—Pp. 11-12.
2. Thorndike, E. L.—The Principles of Teaching—P. 265. (Ed. 1906).

* For our purpose the Book Method may be defined as the method which makes exclusive use of books in which the teacher assigns definite lessons for the pupils to learn as best they can; the Lecture Method, as the method by which the teacher tells the substance of the lesson to his pupils without the aid of books or experimental demonstration, but makes use of black board diagrams and gestures; the Experiment Method, the method through which the teacher imparts the lesson by means of experimental demonstration and nothing more; the Experiment-Note-book (Combination) Method, makes use of note-books in addition to experimental demonstrations.

The Parallel Group Method

To carry out the tests more efficiently, I have made use of parallel groups.* The tests were carried on during the Spring and Fall terms of 1911, and extended over a period of time from April 21st to October 31st, 1911. This prolonged period offered an opportunity to repeat some of the tests the second term and thus verify, to a considerable extent, the work of the first. During the first term, there were sixteen experiments or tests. After a lapse of time, one of them was tested for permanency of acquisition, twice; while four others were each tested once. During the second term, six of the original experiments were repeated. One was tested for permanency of retention twice, and three were each tested once. Altogether a total of thirty experiments were carried out.

The Subjects

The subjects of the tests were about five hundred elementary school boys. With the exception of three or four, all of them were Jewish. About one-third of them were foreign born, and about half had some after-school occupations, such as Hebrew lessons, music lessons, drawing lessons, work and assistance to parents. The average age of the fourteen classes was 13 years, 8 months. But the range of ages is from 11 years to 17½ years. Twenty-eight of the boys wore eye glasses, and thirty-two of them did not see well. Seven had difficulty in hearing. The home environment of all was generally poor. The average intelligence, as far as elementary physics is concerned, was about the same in all classes.

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* "In this method, two classes, approximately equal in number, age, home environment, and capacity, are subjected to different methods or different types of subject-matter and the effect of these different treatments is compared by subjecting both classes or groups to the same test. This method might be perhaps characterized as yielding results less general in their application than the statistical method, but on the other hand, it permits of comparison of the results of disputed methods under conditions where a test of the former type would be impracticable, and the results obtained, is sufficiently suggestive, would warrant the repetition of the experiment until a sufficient number of cases had been accumulated to permit the drawing of general conclusions. Such experiments, carefully planned to account for all known influencing factors, and repeated to discover whether any factors not forseen were really operating, would ultimately yield very valuable results."—Bagley, W. C.—The Scientific Method in Educational Research—N. S. Rev. 6:175:1910.

Table I summarizes all the facts and gives all the information at a glance.

Class	No. of Boys	Average Age		DISTRIBUTION BY AGES														No. Native Born	No. Foreign Born	After-School Occupations					No. who wear Glasses	No. who do not see well	No. who do not hear well
		Yrs.	Mos.	11 – 11½	11½ – 12	12 – 12½	12½ – 13	13 – 13½	13½ – 14	14 – 14½	14½ – 15	15 – 15½	15½ – 16	16 – 16½	16½ – 17	17 – 17½	17½ – 18			Les. in Hebrew	Les. in Music	Les. in Drawing	Assist Father	Work			
7A1	38	12	8		4	6	7	7	5	4	4	1						24	14	16	3	0	12		0	2	1
7A2	36	13	6		1	1	6	7	8	4	6	2	1	1				23	14	10	1	1	2	1	1	3	0
7A3	34	13	8			3	4	11	6	1	6	1	2					24	10	12	6	0	2	0	1	2	1
7A4	33	13	2	1	2	4	3	11	5	3	3	1						25	8	12	2	0	1	2	2	7	0
7B1	33	13	10			1	2	7	7	6	5	1	2	2				19	14	7	2	0	2	1	0	1	0
7B2	36	13	6		2	2	5	6	7	5	7	1			1			17	19	11	4	0	1	0	2	2	0
7B3	33	13	7			1	6	6	5	7	4	2	2					20	13	11	2	0	3	1	0	0	0
7B4	24	13	11		1		3	2	7	6	4	1						14	10	10	2	0	1	1	1	0	0
8A1	34	13	4		0	1		6	7	3	7	5	3		2			24	10	4	4	0	2	3	0	4	0
8A2	37	14	2			1	4	6	6	6	1	5	1	3	4			25	12	6	4	0	1	1	2	2	1
8A4	38	14	0				1	5	7	10	6	8	1					26	12	4	3	1	4	2	1	1	0
8B1	44	14	9					4	5	8	3	10	6	4	2	2		29	15	6	3		4	3	8	2	1
8B2	41	14	8				1	1	2	7	11	10	4	4	1			25	16	2	8	1	2	5	1	2	1
8B3	45	14	6			1		4	6	6	10	9	3	2	3	1		32	13	3	3		5	4	9	4	2
Totals	507	13	10*	1	10	21	42	83	83	76	77	57	25	16	13	3		327	180	114	47	3	49	24	28	32	7

*Average age.

The Material

The course of study of The City of New York assigns the following topics to each of the grades:

7-A Grade—Simple Machines.
7-B " —Mechanics of Liquids and Gases.
8-A " —Sound and Heat.
8-B " —Light, Magnetism and Electricity.

The material of these tests was the prescribed subject matter of the respective grades. No special arrangements, extensions or abridgements were made. The sequence of lessons and the order of topics was preserved as if no tests were carried on. In fact, the aim was to make this a practical class-room test under ordinary class-room conditions.*

In the Book Method the boys were given mimeographed sheets† which contained the appropriate lessons. In the majority of the tests, I have written the lesson myself. In a few cases, I copied it verbatim, from an elementary science book which was expressly written for elementary school use. As far as possible, I tried to make the lesson clear, concise and to the point. The language was carefully suited to the age and capacities of the subjects. Whenever I thought it advisable, I made diagramatic drawings on the sheets.

In the Lecture Method, I repeated practically everything that was written for the Book Method. I tried, as far as possible, to avoid change of text, but not arrangement, to add to, or subtract from, the content of the lesson, or to suggest, in any way, new ideas or lines of thought which were foreign to the Book Method. It must be added, however, that I freely made use of gestures and simple blackboard diagrams. The diagrams were the same as in the Book Method.

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* Meumann and Lay place a special emphasis on class-room experiments. This is the only procedure which will produce practical results that are applicable to actual school work. Tests that are based on nonsense syllables, figures, or other irrelevant material, with a small group of children, under strictly controlled conditions, may have some educational significance: but they certainly are too remote from ordinary school work and every-day class-room conditions to be of immediate practical value.

† The fact that the Book Method was not tried with actual books is a serious criticism on my investigation. I was compelled to use mimeographed sheets because appropriate books were not available.

In the Experiment Method the same lesson was repeated by means of experimental demonstration. Sometimes, the experiment itself did not include as much subject-matter as did the Book and Lecture methods. In such cases the remainder of the facts was brought out by a question, suggestion, or statement. Each experiment, of course, included a description of the apparatus and an informal statement of the aim of the lesson. Wherever practicable, the same introduction that was used in the Book and Lecture methods, was also used in the Experiment Method. Talking during the demonstration was limited. This was deliberately done so as not to combine the experiment with an informal lecture. However, when the experimental process did not seem to be quite intelligible a word here and there was added. The aim, here, was to present the facts experimentally so that the boys would understand them and yet avoid the use of an accompanying lecture. As far as possible, I let the boys draw their own conclusions. In rare cases, one or more boys summarized the facts of the lesson.

I am not forgetful of the fact that this mode of teaching by the Experiment Method will meet with unfavorable criticism. In the nature of the case, I could do no better. If I were to conduct the lesson in the usual manner, I would have a combination of two or more methods. This I tried to avoid. The aim was to find out how much and how well the boys will learn through experiments, pure and simple.

The Experiment-Note-book Method (Combination) made use of note-books in addition to the experiment as it was carried out in the Experiment Method. After the experiment, one or more boys in turn described the experiment, read the card (page 158) and answered the questions thereon. This done, rough sketches of the apparatus were made on scraps of paper. At home, the *Object, Apparatus* and *Operation* were copied verbatim from the card into the note-books; the questions were answered and the diagrams carefully drawn.

Blank Forms

The only blank forms that were used are the "Data Blank" (page 58) and the "Information Blank" (page 59). The Data

Blanks were used to note all important items during the lessons and tests in each method. The Information Blanks were used to show personal data regarding the subjects. The former were filled in by me, and the latter were filled in by the boys, under my direction.

Data Blank

Method: ....

Date: ....Time: ....Grade: ....

No. of Boys: ....

Average Age: ....

Weather: ....

Light in Room: ....

Air in Room: ....

Temperature: ....

Humidity: ....

Previous Hour: ....

	1	2	3	4	5	6	7	8	9	10
Time for Learning:	......	......	......	......	......	......	......	......	......	......
	11	12	13	14	15	16	17	18	19	20
	......	......	......	......	......	......	......	......	......	......
	1	2	3	4	5	6	7	8	9	10
Time for Examination:	......	......	......	......	......	......	......	......	......	......
	11	12	13	14	15	16	17	18	19	20

Minimum Per Cent.:		Av'ge Time Learning:
Maximum Per Cent.:		" " Examination:
Mean Per Cent.:		Mean " Learning:
Average Per Cent.:		" " Examination:

No. Correct for: I:......II:......III:......IV:......V:......VI:.....

% Correct for: I:......II:......III:......IV:......V:......VI:.....

Interest to Teacher: ....

Interest to Pupils: ....

Fatigue to Teacher: ....

Fatigue to Pupils: ....

REMARKS: ....

....

....

....

....(over)

Information Blank

1. Grade ....Room ....Date ....
2. Name ....
3. Age......yrs......mos.   4. Address ....
5. Where were you born? ....
6. How long are you in this country? ....
7. What do you do after school? ....

....

8. Where was your father born? ....
9. What does he do? ....
10. How many rooms do you live in? ....
11. Front or back? ....   12. How many tenants?..........
13. How many brothers have you? ....older........younger........
14. How many sister have you? ....older........younger........
15. How many children are dead? ....
16. Do you wear glasses?........   17. Do you see well?..........
18. Do you hear well? ....   19. Do you like drawing? ....
20. What subject do you like best? ....

....

21. Do you like the sheet method? ....why? ....

....

....

22. Do you like the talking method? ....why? ....

....

....

23. Do you like the experiment method? ....why? ....

....

....

24. Do you like the card-exp.-note book method?..........why?........

....

....

25. If you like any other method, state it. ....

....

MARKS		EFF.	PROF.	DEP.	DEFICIENT IN
	SEPT.				
	OCT.				
	NOV.				
	DEC.				

The Test Questions

Two principles guided in the making of the test questions: (a) The wording of questions in such manner that they could be answered from memory. (b) The wording of questions in such manner that they required reasoning, thought and power in addition to pure memory in order to obtain the correct answer.

In other words, the aim was to test for memory and for "power" and to see how the pupils, taught by the different methods, would respond to each.

To be sure, everything that we should like to have tested—everything that is of real educational value—is, at present untestable.

This, however, does not mean that we can not test the responses, changes of knowledge and definite habits and associations that various methods of teaching produce. And in so far as these can be tested, just so far do they decide the efficacy of this or that method of teaching a particular subject under stated conditions.

In making the questions, care was taken not to favor any one of the methods, either in the content, wording, or arrangement.

Method of Procedure

The writer is well aware of the necessity of giving detailed information as to the exact procedure in any investigation that purports to be exact. But space will not permit extended detail here. The more or less detailed descriptions of the individual experiments will, it is hoped, compensate for this brevity.*

Scoring

In order to have the conditions of scoring as uniform as possible, the examination of all test-papers was postponed until the entire series of experiments was concluded. The manner of scoring was as follows:

1. The basis is 100% for a correct test-paper.

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* Complete description in original MS.

2. If there were five questions, each question received 20%, if the *thought* was correct. More than five questions, or less than five, pro rata.

3. If the answer readily divided itself, proportionate credit was given for correct portions of an answer.

4. Each question was marked individually, correct or incorrect, partly correct or partly incorrect.

5. Each paper received the combined percents of all questions.*

THE EXPERIMENTS, TABLES AND GRAPHS

For our present purpose, an *Experiment* will connote the complete consideration and comparison of the Book, Lecture, Experiment, and (whenever tried) the Combination Methods. All the necessary facts and figures of each *Experiment* are recorded on a TABLE. The attainments (%s) in each method, and the number and per-cent-correct-per-question are graphically represented. Thus each complete *Experiment* consists of three parts: (a) *General discussion,* (b) a *table* and *graphs,* (c) *partial conclusions.*

For the sake of clearness and facility the following symbolical representations are used:

Each Experiment, TABLE and GRAPH is numbered as follows:

Experiments:—*A Series* (Spring term).

EXPERIMENT IA, IIA, etc. indicates that the Experiment was performed during the Spring term of 1911.

TABLE IA, IIA, etc. accompanies..............EXPERIMENT IA, IIA, etc.

Experiments:—*B Series* (Fall term).

EXPERIMENT IB, IIB, etc. indicates that the Experiments were performed a second time during the Fall term of 1911.

TABLE IB, IIB, etc. accompanies..............EXPERIMENT IB, IIB, etc.

Interval Tests:—*A Series.*

EXPERIMENT IA1, IIA1, IIA2, etc. indicates that the tests were repeated after a stated interval of time.

TABLE IA1, IIA1, IIA2, etc accompanies........EXP. IA1, IIA1, IIA2, etc.

Interval Tests:—*B Series*

EXPERIMENT IB1, IIB1, IIB2, etc. indicates that the tests were repeated after a stated interval of time.

TABLE IB1, IIB1, IIB2, etc., accompanies EXPERIMENT IB1, IIB1, IIB2, etc.

This method of scoring has a serious disadvantage in that it does not take account of the individual scores in the total per cents., i. e., A score of 60% may mean, on the basis of five questions to a test, any one of three things:

1. Two and a half questions correcty answered.
2. Five half-questions correctly answered.
3. One whole and three half-questions correctly answered.

However, this not being an investigation of individual attainments, but of class attainments, the results are not seriously impared. In addition, we have the tables and graphs for "number and per cent.-correct-per-question," which very nearly remedy the defect.

EXPERIMENT IA

General Observations

The first experiment of the series was conducted April 21st, 1911, and it consisted of a lesson on the pendulum, taught by the Book, Lecture and Experiment methods. The subject-matter, as it was used in the Book Method, and approximated in the other two, and the test questions are found in Appendix I, page 150, and Appendix II, page 155, respectively.

(a) $7A^3$, the Book Method class, consisted of 37 boys whose average age was 13 years, 8 months. The lesson was given at 9:20 A. M. with nothing but 15 minutes' music practice immediately preceding. The day was clear, and the light and air in the room were good. The temperature was 69° and the humidity, 61°.

(b) The Lecture Method class, ($7A^4$), consisted of 34 boys whose average age was 13 years, 2 months. The lesson was given at 10:40 A. M. with mathematics and drawing preceding it. All other conditions were the same as in the Book Method.

(c) The Experiment Method was tried with class $7A^1$, numbering 33 boys whose average age was 12 years, 8 months. The lesson which was given at 1:40 P. M. followed a heavy program for that day, *i.e.*, Geography test, Grammar, Reading, Composition (Lunch), and a Mathematics test. All other conditions agreed with those of the Book and Lecture methods.

Notes

(a) Book Method:—Some boys only "pretended" that they were studying their lesson-sheets. When I said: "Don't wait for some one else to start. If you know the lesson, hand in your sheet." Three boys returned their sheets immediately and many soon followed. Evidently they did not learn their lesson or they did not know when they had learned it. Some asked for the meaning of "adjust." The last few boys hurried in the test on account of change of classes.

(b) Lecture Method:—The meaning of "affected" was explained. The boys paid very close attention and seemed to be deeply interested.

(c) Experiment Method:—This is my official class. It is next to the last period of the week, which is a library period. They seem to be glad to take up the new work. They are cheerful and happy. Between lesson and test I gave them a short gymnastic drill (2 minutes).

Discussion

The results that were recorded in TABLE IA are:

Methods	*Average*	*Maximum*	*Minimum*	*Median*
Experiment	84%	100%	60%	80%
Lecture	74%	100%	20%	80%
Book	65%	100%	0%	80%

The Book Method class, although it was not burdened with any previous school work, received the lowest scoring of the three (65%).

With an average of 74%, the Lecture Method class takes a nearly exact median position between the other two classes.

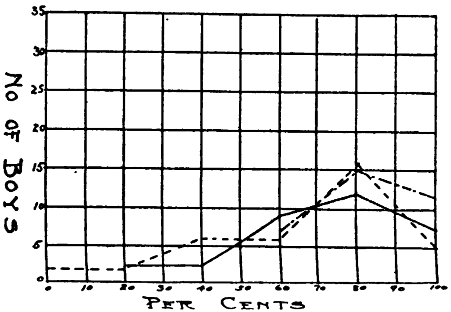
TABLE · IA · THE PENDULUM.

The Book, Lecture, and Experiment Methods Compared.

Method	Class	No of Boys	Date	Time of Day	Av'ge Time (Min) Les	Av'ge Time (Min) Exam	Result Av'ge %	Result Max %	Result Min. %	Result Median %	Weather	Light	Air in Room	Temperature	Humidity	Previous Hours	I No	I %	II No	II %	III No	III %	IV No	IV %	V No	V %
Book	$7A^3$	37	4/21/11.	9.20	13	16	65	100	0	80	CR	G	G	69	61	□	6	16	33	89	25	68	33	89	24	65
Lecture	$7A^4$	34	4/21/11.	10.40	8	15	74	100	20	80	CR	G	G	68	62	MATH DRAW.	12	35	32	94	32	94	26	76	23	68
Exper.	$7A^1$	33	4/21/11.	1.40	9	13	84	100	60	80	CR	G	G	68	62	4/5/11/2/1	21	64	28	84	32	97	30	91	27	82

CR · Clear; G · Good; □ · Music for 15 Minutes, 4 · Test in Geog; 5 · Gram; 11 · Read; 2 : Comp; 1 · Arith Test.

GRAPH · IA · Shows the attainments of $7A^3$ (Book). $7A^4$ (Lecture) and $7A^1$ (Experiment) respectively



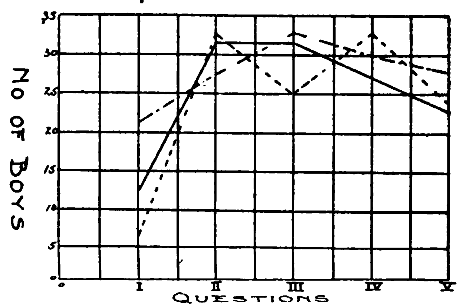
KEY

- - - - Book.

—— Lecture.

- — - — Exper

Graph · 1a · Shows the number of boys in each class, who have answered each question correctly.



The second and third periods (10-11:20 A. M.) are considered by many psychologists and practical teachers as the most advantageous for teaching and learning purposes. And yet as far as actual accomplishments are concerned, the Lecture Method class fell fully 10% below the Experiment Method class.

GRAPH IA plainly shows the superiority of the Experiment Method. The range of individual per cents is from 60 to 100. Whereas in the other two methods the curves extend to 20% and 0%. If we adopt the usual passing mark of 60%, we find that every one of the boys passed on this test.

A careful analysis of Graph 1a, the test questions, and the last half of TABLE IA discloses further interesting facts. Question 1 is mainly a memory question. But the boy's in the Book Method class did not grasp the meaning of that part of their lesson which would satisfy this question. Furthermore, it requires close application and careful thinking to assimilate such matter from the printed page. Only six boys, or 16% of the class, answered this question correctly. Here, again, the Experiment Method leads: 21 boys, or 64% of the class answered the question correctly. The Lecture Method class takes a middle position with 12 boys, or 32% of the class, answering correctly.

In the second question, which is a pure memory question the Lecture Method leads with 94%. This is most probably due to my explanation of "affected." The Book and Experiment methods each follow with 89% and 84%, respectively.

Question 3 is a thought question with a "catch" to it. In order to answer it, memory alone will not suffice. It must be reasoned or thought out. Here the Experiment Method leads with 97%. The Lecture Method is a close second with 94%, and the Book Method lags behind with only 68%.

The Experiment Method is also first in the fourth question. The Book and Lecture methods are second and third respectively. The Lecture Method took an unexpected slump here. Most of the boys answered that both pendulums will make the same number of swings. I can not account for this, except to say that they thought it required an answer similar to the one for question

3. It is easily seen why the Book Method class did so well on this question: the answer was stated almost word for word in the lesson-sheet.

Question 5, being a thought question, again offered a golden opportunity to the Experiment Method. It is distressing to note that the Lecture and Book methods did so poorly; particularly the Book Method. The answer to this question is written, plainly and clearly, in the lesson-sheet. It seems that the boys in the Book Method class readily acquire the habit of relying upon authority. If the question does not immediately recall the authoritative statement of the book, they do not make use even of memory in order to get the correct answer.

Considered from the point of view of time consumed in the actual imparting of this lesson. the Lecture Method takes the least—8 minutes. The most time is consumed by the Book Method—13 minutes. The Experiment Method consumed 9 minutes; but the time that the teacher spent in mere preparation and setting up of apparatus is not considered here. It might be assumed that the time taken in other forms of preparation is the same for all three methods. But for the purpose of the present investigation, only the time consumed in the actual teaching of the lesson is considered.

We have compared the three methods, and have told *what* happened. It is legitimate to ask now *why* it happened. In other words, we want to find, if possible, the underlying causes for these differences in the three methods.

In the first place, the Book Method did not captivate the attention of the boys. This is shown by the mind-wandering that was noted. Whereas the boys in the Lecture and Experiment methods paid close attention. Somebody said, "Interest is the mother of attention." A lesson that arouses no interest, and therefore no attention, is a failure.

Secondly, the boys of the Book Method class could not get the thought from the printed page. They studied words and not ideas. This is proved by the following specimen answers:

"It has to be stopped by the air or the consortary (contrary) pull of gravity."

"A pendulum keeps on swinging because it has force and pulls through the air."

"A pendulum keeps on swinging when once started because the force of gravity can not stop it unless it is stopped by resistance."

"Because it wants to get in its vertical position."

"The pendulum keeps on swinging because the attraction of gravity and it swings the time goes."

"The pendulum keeps on swinging because the attraction of gravity pulls it forward."

"If the wooden pendulum swings forty times a minute, the lead one will swing ten times a minute because it is heavier."

"The lead one swings less than the wooden. Because the leaden one is heavier."

Third, the boys in the Book Method depend upon memory for their answers. This is also proven by the above answers.

Fourth, they do not think independently. They do not show the power of seeing relations and connections as does the Experiment Method class. Questions 3 and 4 of the test (TABLE IA) illustrate this very well. It is plain that the thought expressed in these two questions is one and the same. Therefore, those who answer the one correctly, ought to answer the other correctly also. In other words, those who see the relation between the two, have no difficulty in answering both in the same way. This relation was grasped best by the Experiment Method class and least by the Book Method class. (See Graph 1a.)

Fifth, the Lecture Method class had the advantage of clear and simple language, and in addition they had to exercise their imagination in order to follow intelligently the gestures that were made.

Sixth, the Experiment Method class had a concrete representation and demonstration. A further help was the following table on the black-board:

	LENGTH OF PENDULUM			
Trial	80 cm	45 cm	20 cm	5 cm
1	17	22	33	67
2	17	22	32	68
3	17	22	32	66

Figures show number of swings per 30 seconds.

Partial Conclusions*

The facts of Experiment IA point to the following partial conclusions:

1. On the basis of actual attainments, the Experiment Method of teaching elementary science is the best.

2. The most economical, from the point of view of time, money considerations, class management, and effort, is the Lecture Method.

3. The Lecture Method is the most interesting to the pupil.

4. The Experiment Method excels in inculcating power and independence of thought.

5. No particular "hour" or position on the general program, need be arranged for elementary science.

6. The Book Method is wasteful, uninteresting and barren of good results.

EXPERIMENT IB

General Observations

This Experiment is a repetition of Experiment IA of the term before. The lesson on the pendulum, taught by the different methods, as well as the test questions, are the same. TABLE IB discloses the following:

(a) The Book Method class, numbering 39 boys, was taught November 13th, 1911, at 9:20 A. M. The day was clear and windy. The room was uncomfortably cold; the temperature being 61° and the humidity, 57°. With the exception of about one-third of the class who practiced music, the boys were not burdened with previous work.

(b) The Lecture Method class was taught the same day at 2:20 P. M., the last period of the day, with the work of the entire day preceding. The day was clear and windy, but the room was very warm.

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* The partial conclusions that are stated at the end of each Experiment are based on the facts that it reveals. They are not necessarily related to partial conclusions in other Experiments.

(c) The Experiment Method class was also taught at 2:20 P. M. but two days later. It was cloudy, but the light, air and temperature in the room were normal.

Notes

(a) Book Method:—As in Experiment IA, the boys handed in the lesson-sheets in groups. Before the lesson progressed very far, restlessness was noted. The whistling of the wind outside had more attraction for the boys than the lesson-sheets did.[1] Many questions were asked during the lesson. Some of these were about the meaning of words that appear simple to the adult mind. Other questions were directed to the thought of the lesson. The nature of these questions indicated that the boys understood very little of what they were reading. During the test, questions were asked regarding the meaning of "affected" and "adjust". These were promptly explained.

(b) Lecture Method:—The meanings of "adjust" and "affect" were explained. The close attention that the boys paid to the work in hand is a striking contrast to the listlessness of the Book Method class.

(c) Experiment Method:—The boys sat two in a seat in the front half of the room. They paid close attention to the lesson. The time consumed in this lesson is much less than in the corresponding lesson of last term. This is due to the fact that the pendulums were not each swung for 30 seconds, 3 times. The meaning of "affected" was explained.

Discussion

Although this experiment was conducted with different boys at a different season of the year, and under different relative circumstances, the results obtained, generally agree with those in

1. There is no good reason why this should have been the case, unless it be that the "books" had no power to keep their attention. That wind has no depressing effect upon the mental activity of school children is experimentally proved by E. S. Dexter. He says, "In spite of the fact that we so frequently hear people deploring conditions of considerable movement, and ascertaining that the wind 'makes them nervous,' the curves fail to show that high winds for the climate of New York have any effect disastrous to mental quietude."—Conduct and the Weather—Monograph Supplement No. 6, The Psychological Review, Vol. II, 1899, P. 55.

TABLE IB. THE PENDULUM

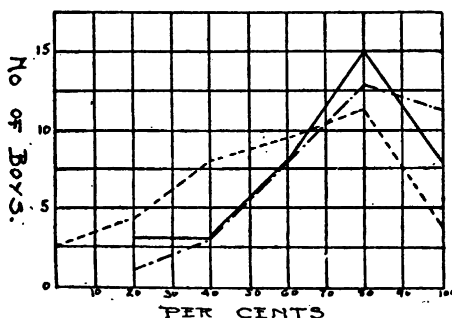
The Book; Lecture, and Experiment Methods Compared.

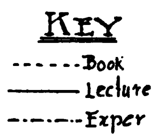
METHOD	CLASS	NO OF BOYS	DATE	TIME OF DAY	AV'GE TIME (MIN) LES	AV'GE TIME (MIN) EXAM	RESULT. AV'GE %	RESULT. MAX %	RESULT. MIN %	RESULT. MEDIAN %	WEATHER	LIGHT	AIR IN ROOM	TEMPERATURE	HUMIDITY	PREVIOUS HOURS	I No	I %	II No	II %	III No	III %	IV No	IV %	V No	V %
Book	7·A¹	39	11/13/11.	9:20	11	17	57	100	0	60	CR	G	G	61	57	□	12	31	30	77	25	64	27	69	17	44
Lecture	7·A³	37	11/13/11.	2:40	5	11	72	100	20	80	CR	G	G	70	65	10/1/5/11/0 9/13/6.	23	62	34	92	35	95	28	76	15	41
Exper.	7·A⁴	37	11/15/11.	2:20	5	10	77	100	20	80	CL	G	G	69	64	1/11/1/4/6/ 0/3/8.	15	41	30	81	32	86	35	95	31	84

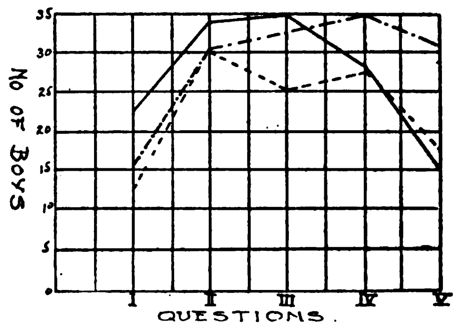
CR· Clear; CL· Cloud; G· Good; □ Music for 15 Min; 1· Arith; 3 Draw; 4· Geog; 5· Gram; 6 Hist; 8 Mus; 9 Pen; 10· Phys Tr; 11 Read; 13 Spell. 0· Lunch hour.

GRAPH IB Shows the attainments of 7·A¹ (Book) 7·A³ (Lecture) and 7·A⁴ (Experiment) respectively.

Graph 1b Shows the number of boys in each class, who have answered each question correctly.







Experiment IA. The Experiment Method leads with an average of 77%. 72% and 57% are the averages of the Lecture and Book Methods. It is interesting to note, that although all three scores are lower than the corresponding ones of last term, the same relative attainments obtain, *i.e.,* the Lecture Method holds the middle ground between the Book and the Experiment methods.

The similarity of results can best be seen when GRAPHS IA and IB are compared.

A consideration of per-cent-correct-per-question shows remarkable agreement in questions 2 and 3. In questions 4 and 5, there is an approximate agreement. A very noticeable disagreement occurs in question one.

Partial Conclusions

The conclusions of Experiment IA (page 68) are confirmed.

EXPERIMENT IA-1

General Observations

The aim of this experiment was to find out how much the boys, taught by the Book, Lecture, Experiment, and Combination Methods would remember after a lapse of seven days. The test questions are the same as in Experiments IA and IB.

(a) The Book Method class (35 present), was tested at 9:20 A. M., the first period, Friday morning. The day was clear and the light, air and temperature were normal.

(b) In the third period of the same day, 10:40 A. M., the Lecture Method class (37 present), was tested. During the first two periods this class had an Arithmetic test and drawing. All other conditions were the same.

(c) Following a heavy program in the morning, and Arithmetic during the first period in the afternoon, 7A[1], the Experiment Method class (35 present), was tested at 1:40 P. M. of the same day. The room was very warm, the temperature being 73°, and the humidity, 66°.

(d) In order to have a lapse of seven days, as in the other methods, the Combination Method class (37 present) was tested four days earlier. The test was conducted during the second period in the morning with Grammar immediately preceding. The weather, air, light, temperature and humidity were normal.

Notes

(a) Book Method:—The boys were told to beat their record of the preceding Friday, although they did not know what it was. They were earnest in their work..

(b) Lecture Method:—The boys were told that this test is given in order to find out how much they do not know. "Two minute setting up drill" was given during the test.

(c) Experiment Method:—7A[1] is my official class. This is the last work period of the week. They look forward to the next period which is a library and "club" period. "Two minute setting up drill" was given.

(d) Combination Method:—This is the first time we are considering the Combination (Experiment-Note-book) Method. The lesson was learned during two periods, one on Monday, eight days before, and one on Tuesday, and each time it was written up in the note-books, the questions of the card were answered and the diagrams drawn. (The cards are found in App. III, page 158.) The actual learning of the lesson consumed about fifty minutes. Much more was consumed in the writing up of the note-books and drawing of diagrams.

Discussion

In the truest sense of the word, this is not a test for permanency, pure and simple. The new lesson in science, that was learned in the interval between the original lesson and the present test, must have had some effect. This new lesson was taught by the Combination Method in the usual manner. Reference to our *Experiment* lessons was carefully avoided, in order to reduce this effect as much as possible. However, it could not be avoided entirely. The quetion is: Did the intervening lesson tend to in-

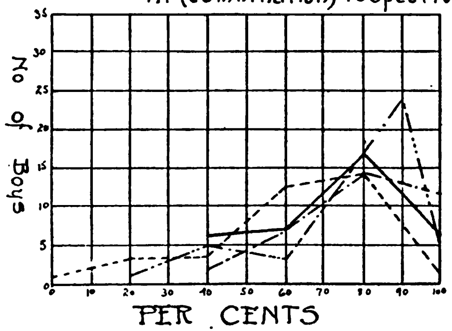
TABLE I·A[1]. THE PENDULUM - 7 DAY TEST

The Book; Lecture, Experiment, and Combination Methods Compared

METHOD	CLASS	NO OF BOYS	DATE	TIME OF DAY	AVGE TIME (MIN)		RESULT				WEATHER	LIGHT	AIR IN ROOM	TEMPERATURE	HUMIDITY	PREVIOUS HOURS	No and % Correct per Question									
																	I		II		III		IV		V	
					LES	EXAM	AVGE %	MAX. %	MIN %	MEDIAN %							No	%	No	%	No	%	No	%	No	%
Book	7·A^3	35	4/28/11	9:20		14	63	100	0	60	CR	G	G	67	60	—	2	6	31	89	29	83	33	94	16	46
LECTURE	7·A^4	37	4/28/11	10:40		14	74	100	40	80	CR	G	G	67	60	1/3.	8	22	36	97	37	100	32	86	23	62
EXPER	7·A^1	35	4/28/11	1:40		16	81	100	40	80	CR	G	G	73	66	6/5/11/4/1.	12	34	32	91	34	97	33	94	30	86
COMB.	7·A^2	37	4/29/11	10:00		17	75	100	20	80	CR	G	G	70	62	GRAM.	9	24	35	92	28	74	36	95	34	89

CR·Clear; G·Good; ·□ Music for 15 Min; 1 Arith Test; 1·Arith; 3 Draw; 4·Geog; 5·Gram; 6·Hist; 11·Read.

GRAPH IA[1] Shows the attainments of 7A^3(Book), 7A^4(Lecture), 7A^1(Experiment), and 7A^2(Combination) respectively



KEY

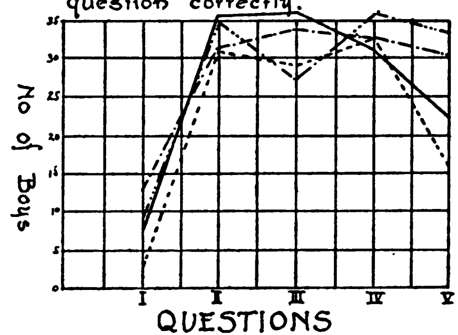
- - - - - - Book

———— Lecture

— —·— Exper

—·······— Comb

Graph 1a[1] Shows the number of boys in each class, who answered each question correctly.



crease or decrease the average results in any or all of the classes? Further: Did the intervening lesson affect the results as far as individual questions are concerned? An examination of the test papers fails to reveal positive information regarding the first question. The influence of the intervening lesson is found both in the Book and Experiment methods; yet the average per cent in the Book Method was increased by 2%, while the average per cent in the Experiment Method was decreased by 3%. These differences are so small that they might have arisen as a result of the differences in mental and physical condition at the time of scoring the two sets, and therefore do not signify anything. We must conclude, then, that the average per cent is not affected by the intervening lesson.

Now, Has the intervening lesson any effect upon individual questions? There are some differences between individual questions, especially in question 1, in this and in the first test; but those differences can not be ascribed to the intervening lesson. A careful examination of the individual test papers affirms this statement.*

The average per cents in this test, as compared with the original test, 7 days before, are:

Method	*Original Test*	*Interval Test*	*Gain*	*Loss*
Book	65%	63%	....	2%
Lecture	74%	74%	....	....
Experiment	84%	81%	....	3%
Combination	....	75%	....	....

From this we might reasonably conclude that, from the point of view of permanency of retention, the three methods, in the order of their superiority are: 1st, Lecture Method; 2nd, Book Method; 3rd, and last, Experiment Method. Permanency of impression is a vital factor in education. This table places the Book Method above the Experiment Method, which is a contradiction of the facts that we gathered thus far. How are we to

* Perhaps the most valuable educational results obtained in such comparison might come from a careful study of individual papers.

reconcile the two? It will be observed that the losses in the average per cents are small; 2% in the Book, and 3% in the Experiment Method. Such losses might be due to a slight difference in scoring, as was stated above; or it may be due to the absence of one or two bright boys and the presence of one or two dull boys in each class. Either of these cases will cause such slight difference in the average per cent.

The important lesson to learn from this is, not that the gain or loss in one method is larger or smaller than in the other, but that the gain or loss in all three methods is small enough to be negligable.

This fact, then, stands out clearly: A lapse of seven days which embraced the regular school work and the regular Saturday and Sunday vacation, produced no appreciable effect upon the relative average attainments in the three methods. In other words, permanency of retention is independent of the method of teaching.

The facts in TABLE IA[1], regarding the Combination Method, compare favorably with those in the Lecture Method. The Combination Method might have approximated the Experiment Method more nearly than any other, were it not for the first question. The explanation which would have satisfied this question was omitted in the lesson. This explains, partly at least, why only nine boys answered it correctly. A comparison of the remaining four questions with the corresponding four questions in the Experiment Method amply bare out the statement that the Experiment and Combination mehods are about on a par. This is in spite of the fact that the Combination Method makes use of note-books in addition to the regular experiment.

From this we must conclude (as far as this experiment is concerned), that the keeping of note-books and the drawing of diagrams do not aid in the teaching of elementary science. Therefore, the time consumed by the pupil in preparing note-books, and the time consumed by the teacher in marking note-books, is largely wasted. Shall we, then, discard note-books altogether? Have note-books any other value, besides increasing the average

attainments? Let us postpone the answer until more facts are obtained from succeeding experiments.

We can not leave this discussion without giving some consideration to question 1. The remarkable slump in this question demands our attention. Comparing TABLE IA[1] with TABLE IA, for this question, we have the following:

Method	*Table 1A*	*Table 1A*[1]	*Loss*
Book	6 Answers	2 Answers	4
Lecture	12 "	8 "	4
Experiment	21 "	12 "	9

How shall we account for this glaring discrepancy? There are two lines of thought that suggest themselves: 1. The psychological effect of a seven-day period between the lesson and the test. 2. The nature of the test question. The first we must dismiss because a similar comparison between the corresponding four questions that remain shows no marked differences.

If we compare question 1 with questions 2, 3, 4, and 5, we find that questions 2, 3, 4, and 5 appeal to the concrete experiences of the pupil. Question 1, on the other hand, is abstract and requires an answer which the boys can not find in their concrete experiences and therefore find it difficult to answer. To tell why a pendulum keeps on swinging requires a close analysis of a situation which is more or less abstract. This is a task too difficult for boys of this age.

The greater loss in the Experiment Method will be treated in later discussion.

Partial Conclusions

The facts of this experiment warrant the following partial conclusions:

1. The permanency of retention of original impressions is independent of the method of teaching.

2. Writing up of note-books and drawing of diagrams do not aid in increasing the boys' knowledge of elementary science.

3. The power of retaining original impressions is not disturbed by intervening lessons, though related to the subject in hand.

4. The work in elementary science must be concrete and must be based on the daily experiences and the observations of the child.

5. The Combination Method consumes more time than any other method, but does not produce better results.

EXPERIMENT IB-1

General Observations

As in Experiment IA[1], the aim of this experiment was to discover the effects of a lapse of time on a lesson learned by the Book, Lecture, Experiment and Combination Method. The test questions and the mode of procedure were the same as in Experiment IA[1] of the term before. The subjects were the same as in Experiments IB.

(a) Book Method:—The test was given Friday at 1:40 P. M. five days after the lesson was learnt. The day was clear and the conditions in the room were normal. The program for the day was particularly heavy. Viz: History, Mid-term test in Grammar and Reading, Geography, Arithmetic.

(b) Lecture Method:—The test was given on the same Friday morning at 9:20 A. M., with nothing but some music practice preceding it. All other conditions were the same as in (a).

(c) Experiment Method:—The test was given at 11:20 A. M. the same day. A Mid-term test in Grammar, and drawing preceded it. The original lesson was given three days before, thus making the interval two days shorter than in the other tests. With the exception of a decrease in temperature of 3°, all other conditions were the same.

(d) Combination Method:—This class was called in for the test at 2:20 P. M., the last period of the same day. They learned the original lesson Monday and Tuesday of the same week.

This makes the interval four and five days. Their program for the day included: Mid-term test in Grammar, Mid-term test in Reading, History, Arithmetic (Lunch), Composition, Music. All other conditions are the same as above.

Notes

The Book, Lecture, and Experiment Method classes were told that the tests were given again in order to improve their mark.

The Combination Method class was deprived of its library and "club" period in order to take the test the same day as the others did. They did not like the substitution. (What is the effect on the results?) As was stated in (d), they learned part of the lesson on Tuesday of the same week. During the lesson, the shades were being mended by a stranger. The distraction was very noticeable.

Discussion

Comparing the results in TABLES IB and IB[1] we find the following:

Method	*Original Test*	*Interval Test*	*Gain*	*Loss*
Book	57%	67%	10%	....
Lecture	72%	76%	4%	....
Experiment	77%	74%	....	3%

In a very general way, this comparison agrees with that in Experiment IA[1]. In this case, however, there is a gain in the Lecture Method, whereas in Experiment IA[1] there was neither gain nor loss. The decrease, after an interval, in the Experiment Method, and an increase in the Book Method, also confirm the result in Experiment IA[1]. But the increases and decreases there were so small that they were negligable. Here the large increase of 10% in the Book Method demands an explanation. If we compare Graphs 1a[1] and 1b[1] we find that the increase comes largely from questions 4 and 5. Both of these are based on the concrete experiences of the child. That is, the answers to these

TABLE I·B[1] THE PENDULUM – 3, 4, & 5 DAY TEST

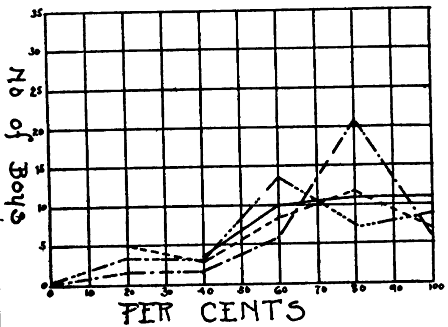
The Book; Lecture; Experiment, and Combination Methods Compared

METHOD	CLASS	NO. OF BOYS	DATE	TIME OF DAY	AV'GE TIME (MIN) LESS	AV'GE TIME (MIN) EXAM	RESULT AV'GE %	RESULT MAX. %	RESULT MIN %	RESULT MEDIAN %	WEATHER	LIGHT	AIR IN ROOM	TEMPERATURE	HUMIDITY	PREVIOUS HOURS	I No	I %	II No	II %	III No	III %	IV No	IV %	V No	V %
BOOK	7·A[1]	35	11/17/11	1·40		9	67	100	20	80	CR	G	G	66	60	6/5/11/4/0/1	7	20	27	77	26	74	35	100	23	66
LECTURE	7·A[3]	36	11/17/11	9:20		10	76	100	40	80	CR	G	G	68	60	□	18	50	31	86	34	94	30	83	24	67
EXPER	7·A[4]	38	11/17/11.	11·20		9	74	100	0	80	CR	G	G	65	60	5/3	9	24	31	82	33	87	37	97	30	79
COMB.	7·A[2]	35	11/17/11	2:20		12	66	100	0	60	CR	G	G	71	62	5/11/6/1 0/2/8	14	40	13	37	25	71	33	94	31	89

The column group I–V is headed "No and % Correct per Question".

CR Clear, G·Good; □ Music for 15 Min, 0·Lunch Hour, 1·Arith; 2·Comp'n; 3·Draw, 4 Geog, 5·Gram Test, 6·Hist; 8·Mus; 11·Read Test.

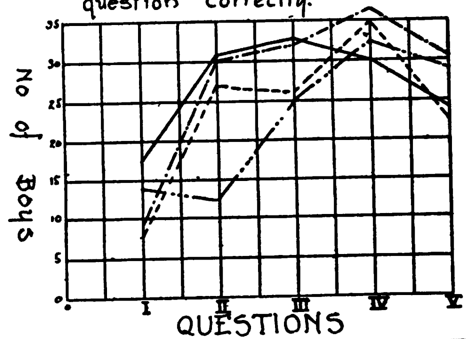
GRAPH I·B[1] Shows the attainments of 7·A[1] (Book), 7·A[3] (Lecture), 7·A[4] (Experiment) and 7·A[2] (Combination).



KEY

- - - - - - - - BOOK
———— LECTURE
—·—·— -EXPER
—··—··—COMB

Graph 1·b[1] Shows the number of Boys in each class who have answered each question correctly.



questions might easily suggest themselves if the boy stops to recall some of his experiences with clocks. If that is the case, why did not the same answers suggest themselves in the first test, five days ago? And why did not they suggest themselves to the boys in the Experiment Method class, where there was a decrease of three per cent.

The explanation might come from a different source. Let us consider the conditions under which the two tests were held. The first test was held during the first period on a Monday morning, after the regular Saturday and Sunday vacation. The room was cold; the temperature being 61°. The second test was held Friday afternoon, at 1:40 P. M. The temperature was normal (66°). Two factors are involved in this consideration: (1) The immediate effect of short vacations and (2) the immediate effect of low temperatures on the mental activity of children.

The first of these questions was investigated by Dr. F. Kemsies. His results, as reported by C. C. Th. Parez, do not at all help us in the present situation: "Continued experiments have shown that the best working days are the first and second after days of rest or holidays. The effect of Sunday's rest often left its mark as late as the following Tuesday afternoon."* This is a direct contradiction of our usual experiences with the "day after" holidays. The Monday morning work is usually uninteresting and unprofitable. But this is the result of limited experience and not of extended investigation. In the absence of contrary scientific facts, we must abide by the facts revealed by Dr. Kemsies. The attempt to explain the increase of 10% in the second test, on the assumption that children do not accomplish their maximum results immediately after a short vacation is, then, a failure.

Let us see if we will meet with greater success in our explanation on the basis of temperature. Dr. William A. Lay says, "Zahlreiche Versuche haben gezeigt, dass die Gewebe und besonders die Nerven und Muskeln der warm-blütigen Tiere und des Menschens ihre höchste Leistung nur bei einer bestimmten Temperatur, dem Optimum, besitzen und dass die Körpertemperatur von

* Parez, C. C. Th.—Mental Fatigue in Germany—Special Reports on Educational Subjects (England) Vol. 9, P. 540.

der Aussentemperatur abhängig ist. Sommerwärme und Winterkälte können also hemmend wirken."* Dr. Dexter is more to the point. He says, "It is a well recognized fact that under conditions of low temperature so large a portion of the vital energy is consumed in keeping the body sufficiently warm to allow a continuance of its metabolic processes, that little is available for deportmental excesses, a condition of comparative lethargy exists.†

Very crudely and to a very slight degree, we have succeeded in explaining away part of that 10% increase. How to dispose of the other part, the unexplained part of the 10% increase, remains an unsolved problem.

It will be noted that the falling off in question 1 is common to all three methods. This is in further agreement with Experiment IA[1].

Here again, the Combination Method did not come up to the Experiment Method. It is 8% behind—an amount large enough to testify to the inferiority of the method in spite of the use of carefully written note-books and neatly drawn diagrams. In the preceding consideration of the Combination Method, an excuse for its poor showing in question 1 was offered. But this same excuse is not valid here. Much to the chagrin and disappointment of those who gloriously fight for the continuance of the use of note-books in connection with elementary science work, we are forced to conclude that the Combination Method is inferior to the Experiment and Lecture methods. Whether or not the use of note-books has some other value remains to be discussed later.

Partial Conclusions

The partial conclusion reached in Experiment 1A[1] (page 76) are confirmed by this experiment.

We must note, however, the marked exception of the increase of 10% in the Book Method.

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* Wm. A. Lay—Experimentelle Pädogogik—P. 40.
† Dexter, E. G.—Conduct and the Weather—Monograph Supplement No. 6—Psych. Rev., Vol. II, P. 44.

EXPERIMENT II-A

General Observations

The subject-matter for this experiment was the Lever (first class). Four classes participated, thus giving an opportunity to test all four methods. The entire experiment extended over three periods in each class. The first two were taken up with the teaching of the lesson by each of the four methods and the third by the test. The material for the lesson in the Book Method and approximated by the other methods is found in App. I, pages 150-152. The test questions are in App. II, page 155.

(a) Book Method:—The first lesson was given Monday, May 1st, at 9:30 A. M. The subject-matter, including the diagrams, which was taken literally from a book,* written for elementary school use, was mimeographed on two sheets which were distributed among the children. (App. I, pages 150 and 151.) The second lesson, which was written on one sheet (App. I, page 152), was given Friday of the same week at 1:40 P. M. This lesson was not copied from a book. Its purpose was to amplify the first lesson. The test was given the following Monday at 9:20 A. M.—seven days after the first lesson and three days after the second. The weather, air and light for all three periods were normal. The temperature (63°) and humidity (58°) were below normal in the second lesson.

(b) Lecture Method:—The subject-matter of the first lesson was the same as in the first lesson of the Book Method, and was given at 2:30 P. M. the same day. The second lesson was given five days later—Friday at 9:20 A. M. In both lessons black board diagrams and figures (similar to those in the Book Method, App. I, pages 151-152) were used. The tests was given on the following Monday at 2:20 P. M. The intervals between the test and the first and second lessons were the same as in the Book Method. The weather was cloudy during the first lesson and

* Wherever the fact that a lesson is copied from a book is noted, the book in question is Woodhull's "Simple Experiments in Physics," Vol. I and II.

the test; clear during the second lesson. The light and air conditions were the same as in the Book Method. The temperature (59°) in the second lesson was lower than in the Book Method.

(c) Experiment Method:—Owing to the usual limitations of a departmental program, the first lesson had to be given two days later than in the Book and Lecture methods—Wednesday, May 3rd, 2:20 P. M. The second lesson was given Friday of the same week at 10:40 A. M. The test was also given two days later than in the other methods. The scope of the lesson was the same as in the Book and Lecture methods. In the second lesson, concrete application was made by showing and discussing the following objects: claw-hammer, grocer's scale, scissors, nippers, also pictures of ice-man's scales and hand truck. The temperature for the first lesson was 69°, for the second 59°, and for the test 76°.

(d) Combination Method:—The first lesson was given at 10:00 A. M., the same day on which the Book and Lecture method were given. The second lesson was given the very next day at 10:40 A. M. In the first lesson the same ground was covered as in the Book, Lecture and Experiment methods. The results were recorded as in the Experiment Method. The usual note-book work was postponed until the second lesson was given. In this lesson the same concrete application was made as in the Experiment Method. The home-work consisted of copying verbatim the *Object, Apparatus* and *Operation* from the card (App. III, page 158). The questions in Result, having been previously answered in class, were answered in the book and the diagrams were drawn. The diagrams in this lesson were unusually complicated and numerous. They drew the apparatus as it was used in the lesson. Then each boy drew pictures of concrete illustrations, i. e., claw-hammer, see-saw, scissors, grocer's scale, steel yard, hand truck, nippers, and anything else that was chosen as an illustration of the lever of the first class.

The test was given on the same day as the Book and Lecture Method tests were given. The light, air, temperature and humidity, during the first lesson, and during the tests were normal. During the second lesson the room was cool.

Notes

(a) Book Method:—First lesson: When the lesson-sheets were distributed the boys were told that they would have the entire period (40 minutes) in which to learn the lesson, and that they would be examined on it later. They read the sheets, the first time, with apparent interest. But the second reading was not commenced immediately. Some shrugged their shoulders indicating that they did not understand the contents. Others asked their neighbors what it all meant. About five came to me and asked what is meant by "Arms". Some could not take the statements "twice the length" and "twice the power-distance" for granted. One suspended his pencil by a string in order to aid him in the mastery of the lesson. Before the period was half over, they looked everywhere but at their lesson-sheets. At the end of the lesson the sheets were collected.

Second lesson: For the second lesson a third sheet (App. I, page 152) was distributed. In addition the two sheets of the first lesson were returned; thus making a complete lesson on the lever of the first class. The third sheet did not prove any more interesting than the first two. I soon noticed vacant staring. One boy read a dime novel. A disorderly boy from another room easily attracted the attention of about three-quarters of the entire class when he pretended to write something on the blackboard. The requests for "leaving the room" were very numerous. Several boys watched me most of the time and when I looked at them they suddenly became studious.

To get the boys interested in the work, I had the lesson read section by section. They paid some attention during the reading; but none after. At the end of the period (40 minutes) the three sheets were collected.

The test: The boys plainly showed that they did not like the test. Many of them sat doing nothing for a long time. They were disagreeably surprised. The tendency to copy was very conspicuous.

(b) Lecture Method:—First lesson: The lesson was taught in about fifteen minutes. The boys seemed to understand the

lesson well. The close attention and deep interest was a pleasing contrast to the listlessness, yawning, stretching and staring of the Book Method class.

Second lesson: The second lesson, including a short review of the first, consumed no more than ten minutes. The boys were surprised to learn that so many common things are applications of the principle of the lever (first class). They were all interested in the lesson. I was pleased to see the intelligent expression and satisfaction in the boys' faces as I recalled the first lesson by means of a black board diagram. Everything indicated that they understood and were interested. After the lesson, the boys did absolutely nothing. Owing to a temporary change of program, they remained in my room the following period, which was spent in walking around the room and looking at various things of interest.

The test: The test was given the last period of the day with a heavy program preceding. The pupils did not show the interest that I expected.

(c) Experiment Method:—First lesson: In the first lesson the boys paid close attention. They were not as interested as the Lecture Method class.

Second lesson: In the second lesson the boys were more interested and paid close attention. The lesson was disturbed by the presence of a visitor and my consequent absence from the room for a short time. The actual teaching consumed fifteen minutes.

The test: I had to explain the second question of the test. The general attitude of the boys was natural.

(d) Combination Method:—First lesson: The boys paid close attention and seemed to enjoy the work.

The second lesson and the short review appealed to the boys.

The test: With the exception of two or three, all of the boys began to answer the questions as soon as they were uncovered. The boys apparently were interested.

The Test

Questions 1 and 3 of the test are primarily memory questions. Questions 4 and 5 are primarily thought questions. Question 2 combines the two with marked leanings toward memory.

Discussion

In this experiment the futility of the Book Method is proved almost conclusively. The great amount of time consumed in the learning of the lesson (80 minutes) and the remarkably low average of 10% are two strong factors militating against its exclusive use. From the point of view of economy of time and efficiency, the Book Method comes lowest in the scale. From the point of view of interest, fatigue, and physical and mental growth, it must also be condemned. The content of the lesson, though not as interesting as it might have been if the quantitative element were eliminated, made no appeal whatever to the pupils. Even the third lesson-sheet proved uninteresting.

A consideration of the responses that the Book Method class made to individual questions is even more instructive. In previous discussion it was hinted that the Book Method might tolerably be used in connection with memory work. Now we must retract even that. Question 3 is primarily a memory question. The answer to it is plainly written and part of it *underlined* in the lesson-sheet. In spite of this, not a single boy succeeded in answering it correctly. The Book Method completely failed on a simple memory question. The question reads: "State the law of the lever. Why do we call it a law?" The answer which is taken from the lesson-sheet is: "Now, according to what we have learned, power multiplied by power-distance equals weight multiplied by weight distance. This is so true in every case, that we call it the *law of the lever*."

Question 1 is another memory question, pure and simple. Only six out of the entire class of 36 boys answered it correctly. To answer this question was even easier than to answer Question 3, because the answer was given in the sheet diagramatically. The only thing the boys had to remember was the diagram. But they did not do that either.

TABLE IIA.

THE LEVER - FIRST CLASS

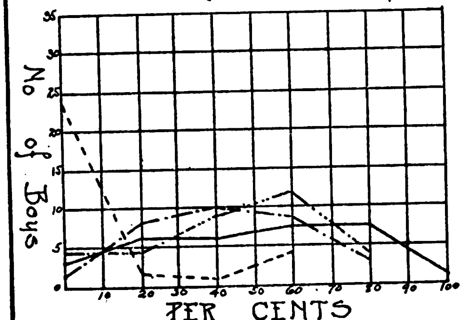
The Book, Lecture, Experiment, and Combination Methods Compared

METHOD	CLASS	No of BOYS	DATE	TIME OF DAY	AV'GE TIME (MIN) LES.	AV'GE TIME (MIN) EXAM	RESULT AV'GE %	RESULT MAX %	RESULT MIN %	RESULT MEDIAN %	WEATHER	LIGHT	AIR IN ROOM	TEMPERATURE	HUMIDITY	PREVIOUS HOURS	I No	I %	II No	II %	III No	III %	IV No	IV %	V No	V %
BOOK	7·A¹	31	5/8/11.	9:20	80	23	10	60	0	0	CR	G	G	70	65	□	6	19	5	16	0	0	1	3	4	13
LECTURE	7·A³	30	5/8/11.	2:20	25	21	48	100	0	60	CL	G	G	70	65	10/1/5/13/6/6	20	67	15	50	6	20	18	60	13	43
EXPER	7·A⁴	31	5/10/11.	2:20	35	20	43	80	0	40	CR	G	G	76	69	1/4/6/13 0/3/8.	24	77	15	48	7	23	2	6	19	61
COMB	7·A²	32	5/8/11.	10:00	60	19	45	80	0	50	CR	G	G	70	66	GRAM	26	81	13	41	13	41	3	9	15	47

(The last ten columns are headed "No and % Correct per Question".)

CR·Clear; CL·Cloudy; G·Good; □ Music for 15 Min; 1·Arith; 3·Draw; 4·Geog; 5·Gram; 6·Hist; 6·Hist Test; 8·Mus; 10·Phys Tr; 13·Spell.

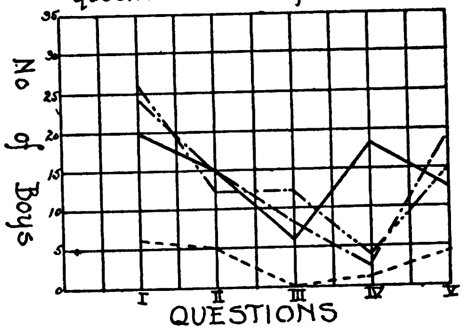
GRAPH II A Shows the attainments of 7-A¹(Book), 7-A³(Lecture), 7-A⁴(Experiment), and 7-A²(Combination) respectively



KEY

- - - - - - Book
———— Lecture
—·—·— Exper
—··—··— Comb

Graph 2a Shows the number of Boys in each class, who answered each question correctly.



Remembering the utter failure in question 3, a memory question, it is interesting to find that one boy answered question No. 4, a comparatively difficult thought question, and that four boys answered No. 5, another thought question, correctly.

Such flat failure of the Book Method, has not, thus far, been recorded. We must concede that the nature of the lesson in itself is such that it does not over-stimulate boys to mental activity. This is proved by the comparatively low average per cents obtained in the other three methods. But more than this was the utter lack of interest in the work. And why was there no interest? Considered from the point of view of an adult, the lesson was simple, clear, amply illustrated, and interesting. Two-thirds of the lesson was written by a man who makes a specialty of writing books in clear, simple language for immature minds. The remaining third, largely an amplification of the first two-thirds was written by me. As was said, the lesson was simple and intelligible enough for an adult. But was it so for the immature minds of 7A boys? A re-reading of the notes compels a negative answer.

Of course, one can not deny the advantage of the Book Method for leisurely study, for lackadaisical reading, and for hard cramming. But these, it is hoped, are extinct in the modern school room.

For the first time in our discussion, does the Lecture Method lead the rest in actual attainment. According to TABLE IIA, the attainments of the four methods are:

Method	*Average*	*Maximum*	*Minimum*	*Median*
Lecture	48%	100%	0%	60%
Combination	45%	80%	0%	50%
Experiment	43%	80%	0%	40%
Book	10%	60%	0%	0%

It is interesting to note that the Lecture Method leads not only in the average per cent but also in the maximum and the median per cents. Before this it has been a close second to the Experiment Method. But in this experiment it is ahead of it by

three per cent. The slight advantage of three per cent, in itself, is not so important in this case, as the condition which brought it about.

The fiigures for "No. and % per question" in TABLE IIA show that, excluding the Book Method, the Lecture Method barely holds its own in questions 1, 2, 3, and 5. But in question 4 it soars far above the other two methods. This is more strikingly brought out by Graph 2a.

No. 4 is a comparatively difficult thought question. Two and three boys of the Experiment and Combination methods respecively, and eighteen of the Lecture Method, more than half of the entire class, succeeded in answering it correctly. This large increase requires an explanation.

When this part of the lesson was taught, a large, clear diagram was displayed. For illustration, a problem was assumed (as was done in the Book Method) and was worked while the boys paid close attention. They watched every step of the process.

Considering this, one might fairly expect more than eighteen of the entire class to have answered the question correctly. This would have been so, if not for the fact that no credit was given for parts of the process in the working of the problem.

A further consideration of TABLE IIA and the Graphs, reveals the fact that the Experiment and Combination methods are about equally effective. The difference being 2% in favor of the latter. This, too, is a fact not previously established.

This would mean that we must retract our adverse criticism of note-book work in connection with elementary science. It would promptly be done if the facts warranted such step. But the small advantage of 2% is not enough contrary proof. As was stated above, a difference of 2% might be caused by the absence of one bright, and the presence of one dull boy during the test.

After all is said in favor of the Combination Method, we can not escape the fact that it is *probably* as efficient as the Experiment Method. This does not mean that we are justified in using it *instead* of the Experiment Method. Are we to disregard the time lost in writing and correcting note-books, and in drawing

diagrams? The extra time spent is not at all commensurate with the small increase of 2%. One might say that if the note-books were eliminated, the average attainment would not be so high. This is not true.—It is not true because the Combination Method consists of the Experiment Method plus all of the extra work entailed in note-book homework. Quite to the contrary—if this proves anything at all, it proves that note-book work is wholly unnecessary; and if we consider the conclusions in preceding Experiments, note-book work may be said to seriously impair the work of the class experiment. May we, then, conclude that note-book work does not materially increase the efficiency of elementary science? In one word, Yes.* But this does not restrain us from seeing other legitimate advantages of the use of note-books. These may be summed up as follows:

1. They aid in reviews of the subject.

2. A carefully kept note-book shows its owner, the order, arrangement, and sequence of topics.

3. They are good reference media.

4. In case of necessity, they may be used as text books.

5. Pupils may be held responsible for a definite amount of work.

6. The keeping of note-books awakens and exercises some abilities of the pupils, i. e., good penmanship, neat and good drawing, clear expression, etc., etc.

7. The pupil has something tangible to work with.

8. Note-book work, especially of this kind, satisfies most parents.

9. Many boys like to keep note-books.

10. Neat note-books are excellent for exhibition purposes.

11. In school systems, where superior officers rarely come in contact with the daily work of the teacher, good note-book work is an acceptable indication of good science work, or good teaching.

* This conclusion is confirmed entirely by the next Experiment, and partially by the second one following. But on the whole, the premises are not strong enough to draw such conclusion.

For purposes of true comparison and fair judgment, it is well to summarize the disadvantages of the use of note-books in elementary science:

1. They do not increase the amount of actual knowledge.

2. Pupils waste an enormous amount of time in writing up note-books and drawing diagrams.

3. Teachers waste an enormous amount of time in marking note-books.

4. The use of note-books encourages copying.

5. Pupils may like to write and to draw; but too often they do not know what they are doing.

6. Pupils very often mistake the mechanical part of writing and drawing for the real lesson which they neglect.

7. Bitter disappointment and irretrievable enmity is caused in cases where the owner of a carefully written and artistically drawn note-books does poorly in recitation work.

8. Note-books unnecessarily increase the amount of written homework.

9. Many pupils can not afford the time after school.

Partial Conclusions

The facts of this Experiment lead to the following conclusions:

1. The most economical and the most efficient method of teaching elementary science is the Lecture Method.

2. The least economical and least efficient method of teaching elementary science is the Book Method.

3. The Experiment is a close second to the Lecture Method in efficiency and in economy.

4. The Combination Method equals the Experiment Method in efficiency, but is far behind it in economy of time and energy.

5. The previous conclusion that elementary science need not have a particular position nor a certain "hour", is confirmed.

6. That the Lecture Method compels interest and attention more than any other method is also confirmed.

7. This Experiment further strengthens the conclusion that note-book work does not affect the final results.*

EXPERIMENT VI-A

General Observations

Experiment VI-A is the first of the series conducted with the 8A classes. The departmental program for these classes was such that extended experimentation was possible. With the exception of one lesson on Heat, all of the lessons were on the subject of Sound. The lesson for this Experiment was on "Vibrating Strings" (App. I, page 152). The test questions are found in App. II, page 155.

According to TABLE I, page 55, the average ages of the three grades are: $8A^1$, 13 years, 4 months; $8A^2$, 14 years, 2 months; $8A^3$, 14 years. Ignoring the six or seven boys who are repeating the work of the grade, the subject of sound is equally new to all three classes.

TABLE VI-A summarizes the facts regarding time of day, weather, air, temperature, etc.

Notes

(a) Book Method:—Boys were rather interested in the lesson-sheets; but were completely surprised when test-questions were uncovered. Three boys tried to "copy".

(b) Lecture Method:—The boys paid very close attention to the lesson. Many sat with "open mouths."

(c) Experiment Method:—The lesson consumed only three minutes. Of course, every piece of apparatus—sonometer, bow, bridges, etc.—was in readiness.

The Test

The test is largely a memory test. The questions are so related to each other, that the answer to any of the first

* Experiments III-A, IV-A, V-A are not given here because, (1) space is limited; (2) previous partial conclusions are confirmed by them; (3) the new facts are given in the "Summary."

TABLE VI-A.

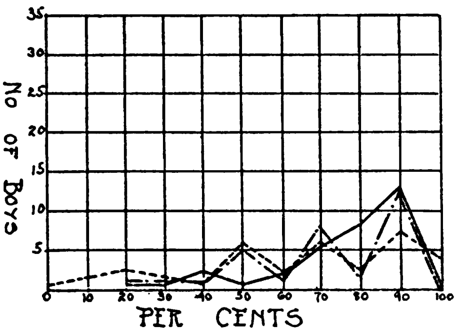
VIBRATING STRINGS

The Book, Lecture, and Experiment Methods Compared.

METHOD	CLASS	NO OF BOYS	DATE	TIME OF DAY	AVGE TIME (MIN)		RESULT				WEATHER	LIGHT	AIR IN ROOM	TEMPERATURE	HUMIDITY	PREVIOUS HOURS	No and % Correct per Question									
																	I		II		III		IV		V	
					LES	EXAM	AVGE %	MAX %	MIN %	MEDIAN %							No	%	No	%	No	%	No	%	No	%
BOOK	$8A^3$	34	3/2/11	10:40	5	12	65	100	0	70	CL	G	G	68	64	* Hist	26	76	20	59	27	80	25	74	25	74
LECTURE	$8A^2$	35	3/2/11.	11:20	4	13	75	100	20	80	CL	G	G	67	62	* 11/4	29	83	30	86	31	91	30	86	25	71
EXPER	$8A^1$	34	3/2/11	2:40	3	x	73	100	20	75	CR	G	G	68	64	* 4/2/14 0/10/1	26	76	26	76	27	80	31	91	29	85

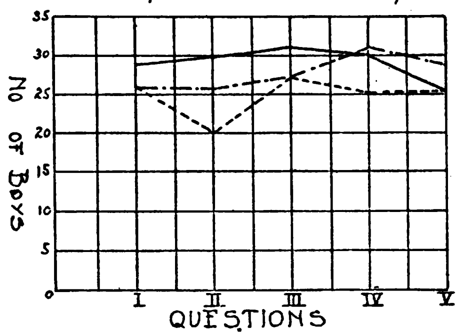
CR: Clear; CL: Cloudy, * Assembly for 60 Min; G: Good; 1: Arith, 2: Comp'n; 4: Geog; 10: Phys Tr; 11: Read; 14: Study; 0: Lunch Hour
X: Time not recorded

GRAPH VI-A Shows the attainments of $8A^3$ (Book), $8A^2$ (Lecture), and $8A^1$ (Experiment) respectively



KEY
- - - - - - - - BOOK
———————— LECTURE
— — —·— EXPER

Graph 6a. Shows the number of boys in each class, who answered each question correctly



three may easily be gotton by elimination; and the answer to the fourth is but a summary of the answers to the first three. In the fifth question opportunity is given for application of knowledge and use of reasoning power.

Discussion

From TABLE VI-A, it will be noted that the Lecture Method is still ahead of the Experiment Method. But the difference between the two is not so marked as in the preceding experiments. The Book Method takes third place with an average of 65%. This is only 10% lower than the Lecture Method. Possibly, the boys in this grade know how to get the thought from the printed page better than their younger brothers in the 7A and 7B.

It is interesting to note that very few boys in each class answered the second half of question 5 correctly. One might assume that boys who play the violin would easily answer this question correctly. They have an "apperceptive mass" which according to the theory of apperception, ought to enable them to master the situation. This is the exact situation that came to mind when the questions were written. I knew that there were four "violinists" in this grade—M. S., H. S., J. E., in 8A[2], and S. C. in 8A[1]—the wording of the question and the nature of the lesson gives them a peculiar advantage. But of all four, only one—M. S.—answered the entire question correctly. Two of them, H. S. and J. E., failed on the second half. S. C. who is particularly interested in science work of all kinds, failed completely.

We hear much of experimentation and theorizing regarding "Transfer" and "Apperception". But nothing definite seems to have been accomplished. The single situation mentioned here, is, of course, no deciding factor. That it is food for serious thought and that it suggests new lines of investigation can not be denied.

Partial Conclusions

This Experiment does not bring out any new facts. It confirms those of preceding experiments.

EXPERIMENT VI-B

General Observations

This Experiment was performed the second term of 1911 and is a repetition of Experiment VI-A, of the term before. The aim, of course, was to verify the results of the first experiment. All conditions for the two experiments were the same except (1) The boys were different, (2) The three lessons were not taught the same day as in Experiment VI-A. TABLE VI-B gives further details.

Notes

(a) Book Method:—Several boys smiled to each other understandingly. Attention to, and interest in, the lesson was not of the best. Boys handed in lesson-sheets in groups, showing that they used no independent judgment.

(b) Lecture Method:—Boys were in earnest and paid close attention. The meaning of "tension" was explained.

(c) Experiment Method:—During the lesson, the boys stood around the desk. Attention and interest were good. As I was working with the sonometer, I unconsciously showed how the violinist produces different tones. This accounts for the much larger number of boys who answered the whole of question five correctly.

Discussion

In this lesson the Experiment Method leads with an average of 82%. The Lecture Method is a distant second with an average of 62%. The Book Method is last, with an average of 63%. The advantage of 16% in favor of the Experiment Method is not only a contradiction of the same experiment of last term, but also a contradiction of several preceding experiments. A good part of this increase is undoubtedly due to the fact that I showed experimentally how a violinist produces tones of different pitch. Expressed in per cents, as computed on the basis of the "number

TABLE VI-B

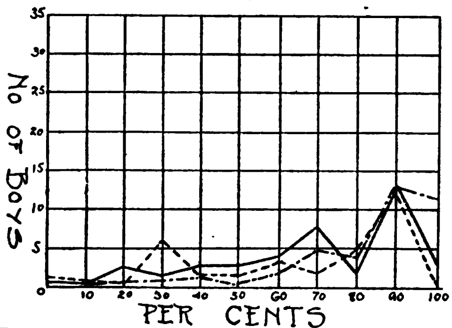
VIBRATING STRINGS

The Book, Lecture, and Experiment Methods Compared

METHOD	CLASS	NO OF BOYS	DATE	TIME OF DAY	AV'GE TIME (MIN)		RESULT				WEATHER	LIGHT	AIR IN ROOM	TEMPERATURE	HUMIDITY	PREVIOUS HOURS	No and % Correct per Question									
																	I		II		III		IV		V	
					LES	EXAM	AV'GE %	MAX %	MIN %	MEDIAN %							No	%	No	%	No	%	No	%	No	%
BOOK	$8A^3$	38	10/9/11	11:20	8	13	63	100	0	70	CR	G	G	68	65	4/1/5	26	68	26	68	25	68	30	79	29	76
LECTURE	$8A^1$	42	10/11/11	9:20	5	14	66	100	0	70	CL	G A	G	67	66	□	28	67	28	67	30	71	38	90	31	74
EXPER	$8A^2$	39	10/13/11	10:00	6	14	82	100	10	90	CR	G	G	67	61	*	37	95	30	77	35	89	36	92	33	85

CR: Clear; CL: Cloudy; G: Good; *: Assembly for 60 Min; □ Music for 15 Min, 1: Arith; 4: Geog; 5: Gram
A: Artificial light

GRAPH VI-B Shows the attainment of $8A^3$(Book), $8A^1$(Lecture), and $8A^2$(Experiment) respectively.



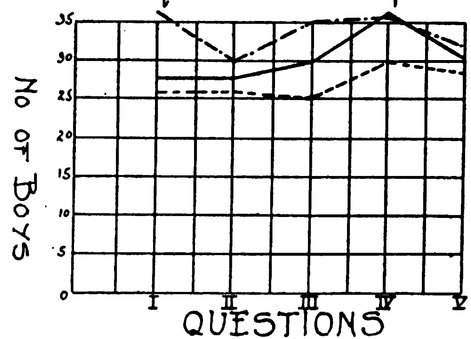
KEY

- - - - - - Book

———— Lecture

—·—·—·— Exper.

Graph 6b Shows the number of boys in each class who answered each question correctly



correct" for question 5, the increase is 5%. But this does not account for the remaining 11%. If we compare this Experiment with Experiment VI-A as to time, we find that in VI-A the Experiment Method consumed three minutes, whereas in this Experiment it consumed six minutes or twice as much. There is then the augmented element of time which accounts for part of the 11%. This does not, however, explain all of the 11%. Nor is it the intention to explain them away. It is best, nevertheless, to discover, if possible, all causes that go to make up a high average per cent, especially if this high per cent is contrary to preceding results. Perhaps another important factor that must be considered in this connection is the weather, light, air, temperature and humidity conditions. TABLE VI-B shows that the Lecture Method class was not particularly favored in this respect.

GRAPHS VI-B and 6b show that the Experiment Method made heavy gains in the first and last questions. The cause for the gain in the last question was given. But why there should be a very marked gain in the first, and not in the second and third question, is not evident. As was said above, the first three questions are of the same nature and any one of them considered together with the other two may be answered by elimination. Furthermore, the answer to question 4 is a summary of the answers to questions 1, 2, and 3. In the Lecture Method we find the peculiarity of a high record for No. 4 (90%), and a very low record for No. 1 (67%), even though No. 4 includes No. 1. Surely one who answers No. 4 correctly can also answer No. 1 correctly. But this is not the case in the Lecture Method. Whether or not boys of this age are able to see the relation between question and question is open to doubt. In the Experiment Method there is no such disparity.

Partial Conclusions

The facts of Experiment VI-B point to the following partial conclusions:

1. The best method of teaching elementary science is the Experiment Method.

2. An increase in the length of "time" of a lesson is followed by a corresponding increase in the average results. (Of course, there is a point beyond which further increase in "time" has a vitiating effect.)

3. An advantageous arrangement or wording of test questions seems to have no effect upon the results.

4. Poor weather, light and temperature conditions have a depressing effect upon the pupils and a consequent decrease in efficiency is the result.

5. The previous conclusions that the Book Method is the poorest of the three methods still holds.

EXPERIMENT VI-A1

General Observations

The aim in this Experiment was to test the power of retention of the three classes taught by the three different methods. For this purpose the test questions of Experiment VI-A were given again seven days after the original lesson and test. As the arbitrary symbol VI-A1 indicates, the test was given in the Spring term of 1911 and is an exact repetition of VI-A as far as circumstances permit it. The test-questions are in App. II, page 155. All data and figures are summarized in TABLE VI-AI. Graphs VI-A1 and 6a1 give the results graphically.

Notes

(a) Book Method:—One boy remarked "We had this test before."—and the others concurred. One boy tried to "copy."

(b) Lecture Method:—Boys were asked to improve on their test of seven days before.

(c) Experiment Method:—This class should have been tested the 9th instead of the 10th of March. But a temporary rearrangement of the program prevented this. The boys were told that this test was very important and that they must not fall behind the other 8A classes. They worked very earnestly and diligently.

Discussion

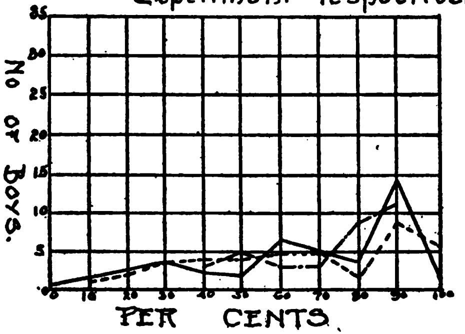
A comparison of TABLES VI-A and VI-A1 shows the

TABLE VI-A[1] VIBRATION OF STRINGS – 7 DAY TEST
The Book, Lecture, and Experiment Methods Compared.

METHOD	CLASS	NO OF BOYS	DATE	TIME OF DAY	AV'GE TIME (MIN)		RESULT				WEATHER	LIGHT	AIR IN ROOM	TEMPERATURE	HUMIDITY	PREVIOUS HOURS	No and % Correct per Question									
																	I		II		III		IV		V	
					LES	EXAM	AVGE %	MAX %	MIN %	MEDIAN %							No	%	No	%	No	%	No	%	No	%
Book.	$8A^3$	41	3/9/11	10:40	-	9	66	100	10	70	CR	G	G	68	61	* HIST	28	68	28	68	28	68	38	93	28	68
LECTURE	$8A^2$	36	3/9/11	11:20	-	11	72	100	0	80	CR	G	G	68	61	* 11/4.	29	81	30	83	30	83	34	94	18	50
EXPER	$8A^1$	33	3/10/11	10:40	-	11	72	90	40	80	CR	G	G	68	62	3/5.	24	73	28	85	28	85	32	97	19	58

CR: Clear; G: Good; * Assembly for 60 Min; 3: Drawing; 4: Geog; 5: Gram; 11: Read.

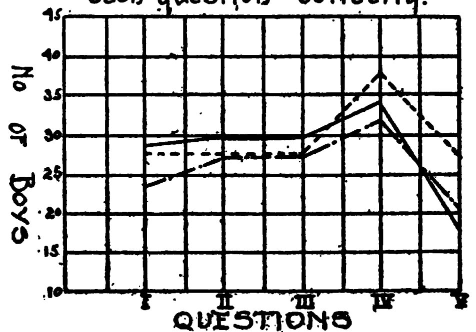
GRAPH VI-A[1] Shows the attainments of $8A^3$ (Book), $8A^2$ (Lecture), and $8A^1$ Experiment respectively.



KEY

- - - - - - Book
———— Lecture
—·—·— Exper.

Graph 6a' Shows the number of boys in each class, who have answered each question correctly.



Lecture and Experiment Methods lost 3% and 1% respictively, and that the Book Method gained 1% in the average attainments. The loss or gain in all three cases is too small to enable us to say that an interval of seven days has an appreciable effect upon the power of retaining ideas gained from the original lesson. This is in accordance with the results obtained in Experiments 1-A1 and 1-B1.

The small falling off in the Experiment and the Lecture methods is, considering the interval of time, natural. But the gain of 1% in the Book Method is in some respects note-worthy.

In the interim between the lesson and the repeated test (seven days later) a new lesson was taught by the Combination Method. It was somewhat related to the lesson in hand, but it did not change the average results. This is a further corroboration of the conclusion in Experiment 1-A1.

Partial Conclusions

The facts of this Experiment sustain the partial conclusions reached in Experiment 1A1.

EXPERIMENT VI-B1

General Observations

Like Experiment VI-A1, this Experiment was undertaken to test the power of retention of the three different classes under the three different methods. The interval of time (seven days) and all other general conditions were the same.

Just as Experiment VI-B contradicted the corresponding Experiment of the term before, Experiment VI-A, and nearly all other previous experiments, so Experiment VI-B1 contradicts its corresponding experiment (VI-A1) and nearly all previous experiments. Reviewing TABLE VI-B1, we note that the Experiment and Book methods each sustained a loss of 2%. The unusual thing here is that the Lecture Method gained 5% after the same lapse of time. All that can be said is that in the exigencies of continued experimentation such exceptions do sometimes

TABLE VI B[1] VIBRATING STRINGS – 7 DAY TEST

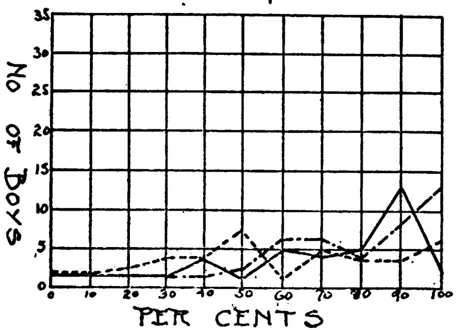
The Book, Lecture, and Experiment Methods Compared.

METHOD	CLASS	No OF BOYS	DATE	TIME OF DAY	AV'GE TIME (MIN) LES.	AV'GE TIME (MIN) EXAM	RESULT AVGE %	RESULT MAX %	RESULT MIN %	RESULT MEDIAN %	WEATHER	LIGHT	AIR IN ROOM	TEMPERATURE	HUMIDITY	PREVIOUS HOURS	I No	I %	II No	II %	III No	III %	IV No	IV %	V No	V %
Book	$8A^3$	39	10/16/11.	11:20	–	12	61	100	0	60	CR	G	G	78	76	4/1/5.	22	56	24	62	23	59	35	87	28	72
Lecture	$8A^1$	38	10/18/11.	9:20	–	11	71	100	0	80	R.	A	G	77	76	□	30	78	30	78	29	76	31	82	31	82
Exper.	$8A^2$	41	10/20/11.	10:00	–	13	80	100	10	90	CR	G	G	77	75	Read	34	83	33	81	32	78	40	99	36	88

(Columns I–V: No and % Correct per Question.)

CR·Clear, R̄·Rain, G·Good, A·Artificial; □·Music for 15 Min, 1·Arith Test, 4·Geog, 5·Gram.

GRAPH VI·B[1] Shows the attainments of $8A^3$(Book), $8A^1$(Lecture), and $8A^2$(Exper) respectively.



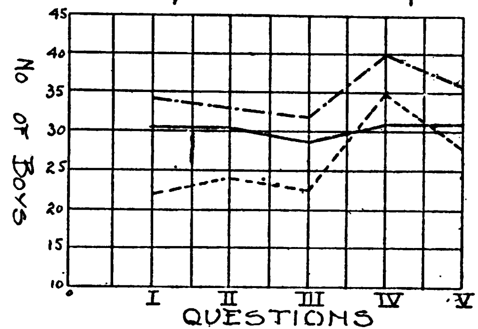
KEY

- - - - - - - - Book

———————— Lecture

—·—·—·— Exper.

Graph 6b[1] Shows the number of boys in each class, who have answered each question correctly.



occur. Inasmuch, however, as this is a bona fida experiment that ranks with all others in this series, the actual facts can not, and must not, be ignored; and the conclusions deduced therefrom must necessarily modify, to a slight degree, our final conclusions.

Partial Conclusions

1. In the Book and Experiment Method classes the power of retaining the original lesson is not seriously impaired by a lapse of time (seven days).

2. The interval of time (seven days) seems to improve the ability of the Lecture Method class.

EXPERIMENT VI-B2

General Observations

So far we have tested the various methods after intervals of seven days. This Experiment was undertaken with the idea of ascertaining the effect of longer periods of time (thirteen, fifteen, and seventeen days) on the power of retaining the original lesson. The original intention was to give each class the same interval of time; but owing to the fact that the original test was given on three different days this was impossible. The small differences between the periods may, or may not, change our results.

The classes, tests, etc., as summarized in TABLES VI-B VI-B1 and VI-B2, are, as far as ordinary school conditions permit, the same.

Discussion

Comparing the results of this test with those of the original test we have:

Method	*Original Test*	*Interval Test*	*Loss*
Book	63%	60%	3%
Lecture	66%	63%	3%
Experiment	82%	79%	3%

Here we note a decrease of 3% in all of the three methods. Not only is it a decrease, but it is a small decrease.

A comparison of the time consumed in the original and interval tests is interesting.

Test	*Book Method*	*Lecture Method*	*Experiment Method*
Original	13 min.	14 min.	14 min.
7 day interval	12 "	11 "	13 "
13, 15, 17 day interval	9 "	9 "	9 "

TABLE VIB²   VIBRATING STRINGS — 13, 15 & 17 DAY TEST

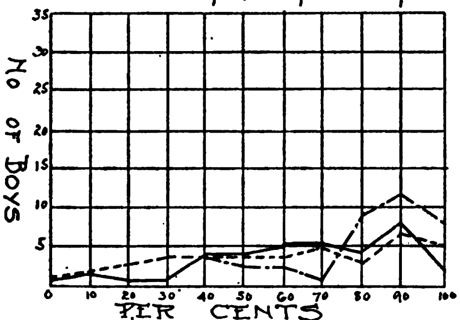
The Book, Lecture, and Experiment Methods Compared

METHOD	CLASS	NO OF BOYS	DATE	TIME OF DAY	AV'GE TIME (MIN) LES	AV'GE TIME (MIN) EXAM	RESULT AV'GE %	RESULT MAX %	RESULT MIN %	RESULT MEDIAN %	WEATHER	LIGHT	AIR IN ROOM	TEMPERATURE	HUMIDITY	PREVIOUS HOURS	I No	I %	II No	II %	III No	III %	IV No	IV %	V No	V %
BOOK	8A³	37	10/26/11.	10:40	-	9	60	100	0	70	CR	G	G	63	58	*Hist	17	46	25	68	24	65	34	92	24	65
LECTURE	8A¹	37	10/26/11.	2:40	-	9	63	100	0	60	CR	G	G	65	62	*/4/2/14 0/10/1.	19	51	27	73	25	68	34	92	24	65
EXPER	8A²	39	10/26/11	11:20	-	9	79	100	40	80	CR	G	G	63	60	*/11/4.	31	79	30	77	32	82	38	97	32	82

(The columns I–V fall under the heading "No and % Correct per Question".)

CR: Clear; G: Good; *: Assembly for 60 Min; 0: Lunch Hour; 1: Arith; 2: Comp; 4: Geog; 10: Phys Tr; 11: Read; 14: Study.

GRAPH VIB² Shows the attainments of 8A³ (Book), 8A¹ (Lecture), and 8A² (Exper) respectively.



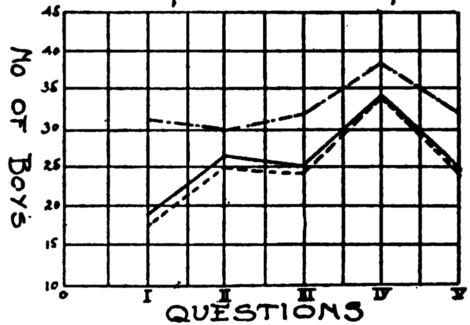
KEY

- - - - - - - Book.

———————— Lecture

—·—·—·— Exper.

Graph 6b² Shows the number of boys in each class, who have answered each question correctly.



Considering that this is average time and not individual time, the decrease in the time consumed in each test is significant. This indicates that the boys were familiar with the work. They had the necessary knowledge "on tap". No unnecessary time had to be used in thinking out original answers.

Partial Conclusions

1. An interval of time—about two weeks—does not seriously affect the power of retaining the original lesson in the Book, Lecture and Experiment methods.

Note.—Experiment VII-A, VII-B, VII-A1, VIII-A, VIII-B1, IX-A, IX-B, IX-B1 are not given here on account of lack of space. The new facts brought out by them will be summarized at the end.

EXPERIMENT X-A

General Observations

This Experiment is different from any we have discussed so far. The aim was to compare the abilities of the Book, Lecture and Experiment Method classes. In order to do this, a general test, composed of questions, culled from previous tests in this series, was given on the same day to all three classes. This makes the intervals between the original lessons and the present test variable, but the same for each question in each of the three classes. The answering of the test-questions and the questionnaire (App. II, page 156) consumed in each case a full period—40 minutes. The conditions under which the tests were given are summarized in TABLE X-A.

The Test

The test-questions were chosen from all other preceding 8A tests of this series. Care was taken not to have any one test predominate. The questions as they are, require a fair knowledge of the entire work that was covered in this series. The test, therefore, is thorough, comprehensive, and representative.

The Questionnaire

The quetionnaire was given for the sole purpose of knowing the sentiments of the boys in the three classes. As stated in the questionnaire parenthetically, the boys were directed to answer the questions plainly, honestly and fearlessly.

Prof. G. S. Hall's investigation proved that the testimony of school children is unreliable. While I do not regard their testimony as decisive, I think, nevertheless, that the boys in this grade and of this age can give us a fair idea of their attitude toward the three methods of teaching.

Discussion

It is very interesting to note that there is no great difference in the average attainments among the Book, Lecture and Ex-

TABLE X-A

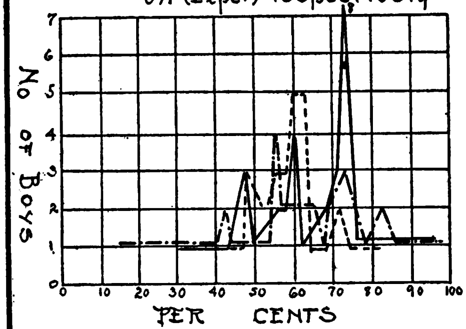
SEMI-FINAL TEST

The Book, Lecture, and Experiment Methods Compared

METHOD	CLASS	NO OF BOYS	DATE*	TIME OF DAY	AVGE TIME (MIN) LES	AVGE TIME (MIN) EXAM	RESULT AVGE %	RESULT MAX %	RESULT MIN %	RESULT MEDIAN %	WEATHER	LIGHT	AIR IN ROOM	TEMPERATURE	HUMIDITY	PREVIOUS HOURS	I No	I %	II No	II %	III No	III %	IV No	IV %	V No	V %	VI No	VI %	VII No	VII %	VIII No	VIII %
Book	$8A^3$	38	4/27/11.	10:40	-	-	56	81	29	58	CR	G	G	65	62	*Hist	29	53	37	97	36	95	0	0	3	8	25	66	14	37	23	61
Lecture	8A	34	4/27/11	2:20	-	-	61	96	31	60	CR	G	G	69	63	*/4/2/14/0 10/1.	22	65	28	82	34	100	3	9	11	33	16	47	19	56	26	76
Exper	$8A^2$	37	4/27/11.	11:20	-	-	59	98	17	60	CR	G	G	66	63	*/11/4.	21	57	34	92	35	95	8	22	15	41	11	30	15	41	26	70

CR: Clear; G: Good; * Assembly for 60 Min; 1: Arith; 2: Comp; 4: Geog; 10: Phys Tr; 11: Read; 14: Study; 0: Lunch hour

GRAPH XA Shows the attainment of $8A^3$ (Book), $8A^1$ (Lecture), and $8A^2$ (Exper) respectively



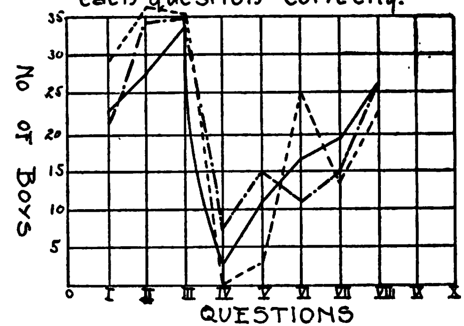
KEY

- - - - - - Book

——— Lecture

—·—·— Exper

Graph 10a Shows the number of boys in each class, who answered each question correctly.



periment methods. TABLE X-A gives the following results: Lecture Method, 61%; Experiment Method, 59%; Book Method, 56%. The difference between the Lecture and Experiment methods is 2%, and between the Lecture and Book methods, 5%. If we arrange the three methods in the order of efficiency, we have: 1st, Lecture Method; 2nd, Experiment Method; 3rd and last, Book Method. We must not forget, however, that this arrangement is based on very small differences in average per cents. In previous discussions a small difference of 2% was considered negligible on the ground that such small difference might be caused by a slight difference in the mental and physical condition of the scorer, or the presence of one or two bright boys and the absence of one or two dull boys. Considering the results in this light, we may say that there is really no difference between the Lecture and Experiment methods. If there is no difference in efficiency, and all of the arguments in the early part of this dissertation—economy of time, expenditure of money, school and class management, saving of energy, high degree of interest, less fatigue, etc.—in favor of the Lecture Method, we must conclude that the Lecture Method is the better of the two methods.

The three methods in the order of efficiency and economy are, then, 1st, Lecture Method; 2nd, Experimental Method; 3rd, Book Method.*

All that has just been said, must not be construed as final. It is a partial conclusion, not having any less and not much more weight than any of the preceding or succeeding partial conclusions.

This Experiment offers a splendid opportunity to study the effect of time upon a lesson taught by the three differen methods. The following tabulation, which gives the absolute and per central number of correct answers for each question, will help us to a clear understanding:

* This leaves out the Combination which must be given third place when all four methods are compared.

Question	Method	Original test		Interval‡	First repetition		Interval‡	Present test	
		No.*	%†		No.*	%†		No.*	%†
1.	Book	39	98	....	......	......	35 da	29	53
	Lect.	36	95	....	......	......	35 da	22	65
	Expt.	35	97	....	......	......	35 da	21	57
2.	Book	31	79	....	......	......	21 da	37	97
	Lect.	32	91	....	......	......	21 da	28	82
	Expt.	31	89	....	......	......	20 da	34	92
3.	Book	34	89	....	......	......	21 da	36	95
	Lect.	30	86	....	......	......	21 da	34	100
	Expt.	31	89	....	......	......	20 da	35	95
4.	Book	1	3	....	......	......	21 da	0	0
	Lect.	7	20	....	......	......	21 da	3	9
	Expt.	11	31	....	......	......	20 da	8	22
5.	Book	15	41	14 da	3	9	42 da	3	8
	Lect.	27	75	14 da	15	41	42 da	11	33
	Expt.	20	58	14 da	8	24	42 da	15	41
6.	Book	14	38	14 da	16	44	42 da	25	66
	Lect.	22	61	14 da	19	51	42 da	16	47
	Expt.	15	41	14 da	24	71	42 da	11	30
7.	Book	26	76	7 da	28	68	56 da	14	37
	Lect.	29	83	7 da	29	81	56 da	19	56
	Expt.	26	76	8 da	24	73	56 da	15	41
8.	Book	25	74	7 da	38	93	56 da	23	61
	Lect.	30	86	7 da	34	94	56 da	26	76
	Expt.	31	91	8 da	32	97	56 da	26	70

*. Number of boys who answered correctly.
†. Per cent of boys who answered correctly.
‡. Since the original test.

Disregarding the method of teaching and the character of the questions, we note that the greater the interval of time between the original lesson and the test, the less permanent is the retention. This statement is based on the following summary of the above tabulation (the increases and decreasss are obtained by comparing the absolute number of boys in each class who answered correctly in each of the interval tests):

After an interval of seven (7) days there are:
- 4 increases in the absolute number of correct answers.
- 1 decrease in the absolute number of correct answers.
- 1 no change.

After an interval of fourteen (14) days there are:
- 2 increases in the absolute number of correct answers.
- 6 decreases in the absolute number of correct answers.

After an interval of twenty-one (21) days there are:
- 5 increases in the absolute number of correct answers.
- 4 decreases in the absolute number of correct answers.

After an interval of thirty-five (35) days there are:
- 0 increases in the absolute number of correct answers.
- 3 decreases in the absolute number of correct answers.

After an interval of forty-two (42) days there are:
- 1 increase in the absolute number of correct answers.
- 5 decreases in the absolute number of correct answers.

After an interval of fifty-six (56) days there are:
- 0 increases in the absolute number of correct answers.
- 6 decreases in the absolute number of correct answers.

What is true of the absolute number is generally true of the per central number of increases and decreases.

It is plain, then, that as the interval of time increases the power of retention decreases. This conclusion is directly opposed to what Wm. H. Pyle says: "An immediate memory test probably gives a fair index of permanent retention, also of habituation time, a good record meaning short habituation time and good retention."[1]

Let us study the situation more carefully. Let us see, first, how the power of retention is affected by the nature of the question (material to be remembered). For the present purpose, questions 1, 2, 5, and 8 may be called memory questions; 3, 4, 6, and 7 may be called thought questions. In question 1 there is a heavy falling off after an interval of 35 days. In question 2 there is a slight gain for the Book and Experiment methods after an interval of 21 days; in question 5, there is again a decided loss after intervals of 14 days and 42 days. In

1. Pyle—Retention as Related to Repetition—Jour. of Ed. Psych., Vol. II, 1911 P. 320.

question 8 there is a decided gain after an interval of 7 days, but this is changed to a slight loss after an interval of 56 days. For an interval of 21-56 days, 3 of the 4 memory questions sustained a decrease. The fourth (No. 2) gained a slight increase for the Book and Experiment methods, and suffered a decrease for the Lecture method. On the whole, memory work is very seriously affected by the elements of time.

A similar analysis of the results for the thought questions (3, 4, 6, and 7) points to the same conclusion.

We must conclude, then, that memory work and thought work are equally impaired by a considerable interval of time (20-50 days).

Since the loss in average attainment is general, let us consider it from another point of view. Let us consider it from the point of view of method. Which of the three methods sustained the greatest loss? Which the least? In order to assure a just comparison, we must take into account only those questions in which all of the three methods sustained losses after an interval of 21-56 days. Furthermore, the comparison must be made on a per cental basis:

BOOK METHOD

Questions	*Absolute number of correct answers*		*Per cent. loss*
	Original test	*Interval test*	
1	39	29	26
4	1	0	100
5	15	3	80
7	26	14	46
8	25	23	8
	Total per cent loss		260

LECTURE METHOD

Questions	Absolute number of correct answers		Per cent. loss
	Original test	Interval test	
1	36	22	44
4	7	3	57
5	27	11	55
7	29	19	34
8	30	26	13
	Total per cent loss		203

EXPERIMENT METHOD.

Questions	Absolute number of correct answers		Per cent. loss
	Original test	Interval test	
1	35	21	40
4	11	8	27
5	20	15	25
7	26	15	42
8	31	26	16
	Total per cent loss		150

This leaves no doubt as to the standing of the three methods. The differences between the Experiment and Lecture methods and the Lecture and Book methods are so great that an attempt to explain them away must prove futile. There can be nothing plainer. We have here extremely valuable proof that the Experiment Method can withstand the "ravages of time" fairly well. The worst in this respect is the Book Method. The Lecture Method takes the median position between the two extremes.

Now let us see what the boys, themselves, have to say on the subject. The questionnaire consists of six questions (App. II, page 156) which were answered after the test-questions were answered. The first four are general in their scope. It is neither profitable nor desirable to give space to a discussion of them here.

The answers to questions 5 and 6 are considered only in so far as they have anything to do with the method of teaching. First, the popularity of each method is indicated by placing next to it the number of votes it received. Second, some specimen answers and suggestions, both favorable and unfavorable are given:

BOOK METHOD CLASS

Book Method	8	votes
Lecture Method	1	"
Experiment Method	21	"
Combination Method	1	"
Laboratory Method	1	"
Meaningless answers	3	"
*No answers	3	"

Here are some of the specimen answers and suggestions:

"I think I would like to be taught by experimenting and not by way of writing out and studying."

"I suggest one boy should perform the experiment in the class."

"I like to be taught by experiment."

"I would like to be taught that every boy should have a desk on which he could do the experiment himself."

"I like to be taught by the method we use."

"By seeing it experimented by the teacher."

"I like to be taught by the method of experiments and not the method of tests."

"I would suggest that the boys should be taken to some place where they will really see the solids expand. I believe that you explain very good but still in all one can not have the real thought how the solids expand."

"I hate to be taught by note-book or cards. The best method I think is to give out sheets or to study sheets in the class-room."

"I suggest that we get down to work and get experiments in science and not have tests every science period on rubbish. By 'seeing is believing' and not by reading it off a paper and having a test on it the next minute. I do not believe in having a test on how old I am."

* Some boys had no opportunity to finish.

"I like to be taught by the method I am taught now."

"I think it would be good to teach by experimenting."

"I would like to be taught by the method of showing with apparatus and working it and to explain."

"I like to be taught by the method that you should explain it all."

"I like to be taught by the same method as we have been taught before." (Combination Method.)

LECTURE METHOD CLASS

Lecture Method	11	Votes
Book Method	3	"
Experiment Method	8	"
Experiment—Lecture—Text-book Method	1	"
Meaningless answers	8	"
No answers	3	"

Specimen answers and suggestions:

"I like to be taught by the method we have now."

"Any method the teacher chooses I like to be taught."

"I like to be taught by experiment."

"I like best the method we are using."

"I think this method to be very good."

"I like to be taught by the experimental method and to read about the thing."

"I like to be taught with good explanations."

"I like to be taught by experiments."

"I like the experiments, reading of books and lecturing."

"I like to be taught by giving out sheets."

"I like to be taught by a science book and tested frequently."

"I would like to hear lectures of it and when I go home I would like to try the experiment."

"By experiment method."

EXPERIMENT METHOD CLASS

Experiment Method	18	Votes
Lecture Method	3	"
Book Method	0	"
Combination Method	4	"
Laboratory Method	1	"
Lecture—Experiment Method	1	"
Meaningless answers	2	"
No answers	8	"

Specimen answers and suggestions:

"I like to be taught in the method we are taught at present."

"I like it by the method we are now taught."

"We like to be taught by the method you are teaching us now."

"I like to be taught by speech and diagrams."

"The method Mr. Mayman uses suits me."

"I like to be taught in a quick method each day an experiment."

"By an explanatory method."

"I like to be taught by the same method as you kept on for the whole term." (Combination Method.)

"The method I would like to be taught is to perform the experiments but not to write them up except the result which is necessary."

"I like to be taught by the method you taught us."

"I like the present method."

"I think that when we have committees to look at the things we ought to pick them out alphabetically." (Whenever the details of any experiment were so minute that the entire class could not very well see them, representative committees were chosen to observe and to report.)

"I like to be taught by the same method as we were having before." (Combination Method.)

"I like to be taught by the methods of good explanations and good diagrams."

"I can not see any better method of teaching or being taught than the one you use in science, namely showing us the operation and convincing us."

"I like to be taught in the same method that you teach us, because we don't get much homework but we get enough class-work to learn."

"I like to be taught when illustrations are showed on the board and everything to be explained in writing and not give an oral explanation of the experiment."

It is needless to say which of the three methods is the most popular among the boys. The Lecture Method class seems to be rather satisfied. It is the only class that did not cast a majority vote for the Experiment Method. Its minority vote of eight in favor of the Experiment Method is only three less than for the Lecture Method. The Book Method received the lowest number of votes.

The boys who cast this vote are in the 8A grade. Their average age is 13 years, 10 months. It seems to me that such

boys know what they say when they say it. If we do not rely entirely upon their judgment, we ought, at least, keep in mind their sincere suggestions when we plan a lesson or a series of lessons in elementary science.

Partial Conclusions

1. From the point of view of efficiency the methods are: 1st, Lecture Method; 2nd, Experiment Method; 3rd, Book Method.

2. Thought work, as well as memory work is seriously impaired by an interval of time (21-56 days).

3. The power of retention is inversely proportionate to the length of time.

4. With regard to permanent retention, the methods rank as follows: 1st, ExperimentMethod; 2nd, Lecture Method; 3rd, Book Method.

5. In the order of their popularity among the boys, the methods are: Experiment, Lecture and Book Method.

Note.—Experiment XI-A, XI-B, XII-A, XII-A1.

EXPERIMENT XIII-A

General Observations

The lesson on the condenser was given in the Spring term of 1911 to the graduating classes, The lesson was very difficult. Even experimental demonstration does not prove very much to young minds. The conditions attending the lesson and test are given in TABLE XIII-A. The lesson-sheet which served as a basis for the Lecture and Experiment methods is found in App. I, page 153.

Notes

(a) Book Method:—Boys were disgusted with the lesson-sheets. The boys are very bright and the lesson-sheet does not seem to furnish enough mental exercise for them. The meaning of tin-foil was explained.

(b) Lecture Method:—Many peculiar questions were asked. Some of these are: "What do you call that brass thing on top of the Electrophorus?" "How do you spell *filge*?" "If I write *tin-filings* is it alright?" "How do you call that brass thing with the handle?" etc., etc.

(c) Experiment Method:—During the Experiment I had a feeling of hurry. It seems now that I did not make a sufficiently strong impression upon the boys. The apparatus used was: home-made Leyden jar, dissectable Leyden jar, discharger, electrophorus for charging, glass plate, and two tin shoe box covers.

The Test

The test (App. II, page 156) though calling largely for memory work is, nevertheless, very difficult. With the exception of questions 2 and 3, the test might prove too difficult even to high school pupils. The intention was not to make it difficult but to make it cover the ground of the lesson.

Discussion

The average per cents for the three methods are: Lecture Method, 65%; Experiment Method, 61%; Book Method, 60%. The differences among them are not very marked. This is the first time in the 8B Experiments that the Lecture Method class reached a higher average than the Experiment Method class.

As was noted above, the lesson in the Experiment Method class was taught hurriedly and the boys failed to get the essentials. This undoubtedly accounts for the low attainment.

It is interesting to note that the median per cent (65%) is the same in all three classes.

In one of the preceding Experiment the question of "Expression" was discussed. A similar discussion can be carried on in conjuction with every Experiment; but that was found to be impracticable. The discussion was deliberately reserved to one Experiment with the intention of making it a "type" discussion.

TABLE XIII A

THE CONDENSER

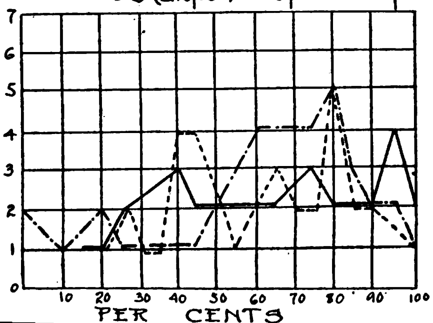
The Book, Lecture, and Experiment Methods Compared

METHOD	CLASS	NO OF BOYS	DATE	TIME OF DAY	AV'GE TIME (MIN) LES	AV'GE TIME (MIN) EXAM	RESULT AVGE %	RESULT MAX %	RESULT MIN %	RESULT MEDIAN %	WEATHER	LIGHT	AIR IN ROOM	TEMPERATURE	HUMIDITY	PREVIOUS HOURS	I No	I %	II No	II %	III No	III %	IV No	IV %	V No	V %
Book	$8B^3$	33	3/15/11.	10:00	11	12	60	100	20	65	CR	G	G	67	61	Math	21	64	28	85	26	79	15	45	16	48
Lecture	$8B^2$	29	3/15/11	1:00	6	12	65	100	15	65	CR	G	G	70	65	5/1/11/4/0.	26	89	23	79	23	79	13	45	11	38
Exper.	$8B^1$	33	3/15/11.	1:40	6	11	61	100	0	65	CR	G	G	69	65	11/2/1 6/0/14.	29	88	24	73	27	82	14	43	13	39

(The last ten columns are headed "No and % Correct per Question".)

CR: Clear; G: Good; 0: Lunch hour; 1: Arith; 2: Comp; 4: Geog; 5: Gram; 6: Hist; 11: Read; 14: Study.

GRAPH XIII B Shows the attainment of $8B^3$ (Book), $8B^2$ (Lecture) and $8B^1$ (Exper) respectively.



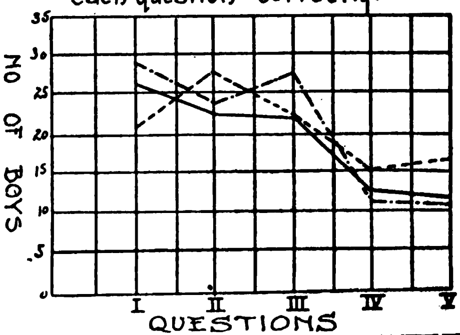
KEY

- - - - - - - - Book

———————— Lecture

—·—·—·— Exper.

Graph 8b Shows the number of boys in each class, who answered each question correctly.



Similarly, the discussion of "spelling" is confined to the present Experiment only. Not that the question of correct spelling is limited to this Experiment alone, but because in this Experiment, as well as in Experiment XII-A, the incorrect spelling is so very marked that the discussion is undertaken.

None but those who read the answers to the questions seriatim, is struck so forcibly with the very poor spelling in the Lecture and Experiment Method classes. The spelling in the Book Method class, is, by contrast, generally good. The reason for this is evident. In reading the lesson-sheet the boys must necessarily look at individual words. New words attract and hold their attention for a while. Looking at individual words produces a mental picture of it which aids in the correct spelling of the same word. On the other hand, the Lecture and Experiment classes get verbal images only. They either depend upon their knowledge of phonetics or upon a guess for the correct spelling of a new and unfamiliar word—mostly it is the latter.

In order to prove my contention I might take the same word or words and note its spelling in each paper of each set and then show my results in tabulated form. But this is not an investigation of spelling. The question of spelling is brought in here only as an interesting side-line, as it were. For our present purpose, a few glaring errors in spelling from the Lecture and Experiment Method papers will suffice.

Lecture Method:—filge (foil), chane (chain), condencer (condenser), Layden (Leyden), nob (knob), foiler (foil), forter (foil), leyden (Leyden), biger (bigger), attaced (attached), condensor (condenser), fork (foil).

Experiment Method:—leyden (Leyden), condence (condenser), coopper (copper), led (lead), puting (putting), toches (touches), condencer (condenser), lyden (Leyden), leydin (Leyden), Electric (electricity).

Partial Conclusions

1. The Lecture Method is the best method of teaching elementary science.

2. As far as the actual teaching of the lesson is concerned, the time consumed is the same in both the Lecture and Experiment methods.

3. The Book Method is wasteful of time.

4. The boys in the Lecture and Experiment Method classes spell not only new scientific words poorly, but also the ordinary spelling is not up to the standing. The boys in the Book Mtehod class do much better.

EXPERIMENT XIII-A1

General Observations

After a lapse of 21 days, the test of Experiment XIII-A was repeated. As in other interval tests, the object was to discover the effects of time on original impressions, in general, and how the interval affected each method of instruction in particular. All conditions under which the test was given are summarized in TABLE XIII-A1.

Notes

(a) Book Method:—The boys expressed their dislike of the test by raising both hands heavenward. Grimaces and frowns were other expressions of disgust. The temptation to "copy" was very great.

(b) Lecture Method:—The clique of very big boys (seven in number) returned their papers without writing anything on them. They were entirely dismayed. At first they did not know what to do. One was struck with the idea of returning the blank paper and promptly executed it. The rest of the clique followed. Several boys kept their papers very long in the hope of getting some sort of inspiration.

(c) Experiment Method:—The surprise and consequent disgust which the other classes showed were conspicuous by their absence. The boys settled down to business immediately and worked diligently.

Discussion

The average attainments of the original and interval tests are:

Method	*Original Test*	*Interval Test*	*Loss*
Book	60%	23%	37%
Lecture	65%	34%	31%
Experiment	61%	37%	24%

One can hardly conceive of such heavy losses in a short interval of 21 days. In previous interval tests, the intervals were as long as 56 days, but no such appalling losses were recorded.

The most decisive factor in this case is not the period of time but the difficulty of the original lesson. In explaining the situation, I can not improve upon the *notes* that I took in connection with the scoring:

BOOK METHOD:—Throughout there seems to be a tendency to confuse electroscope with condenser.

Leyden jar and electroscope are confused very often.

B——, one of the brightest boys, received 0%.

The number of failures is constantly increasing. They do not seem to remember anything.

Their words are all jumbled. They have no concrete images, etc.

There is an absolute disregard for facts. They talk disconnectedly.

EXPERIMENT METHOD:—The boys mistake electroscope for electrophorus and condenser.

F——, who works for an electrician, received 0%.

Boys remember parts of the apparatus but do not remember what was done with it

From this astounding battle with the interval of time and the difficulty of the lesson, all of the methods emerged very badly crippled. They are beaten almost beyond recognition. We must note, however, that the bravest of all was the Experiment Method. It lost 24%, while the Lecture and Book Methods lost 31% and 37% respectively. Considering the difficulty and the importance of the battle, we must award the Experiment Method "honorable mention" at least.

Partial Conclusions

1. An interval of time (21 days) seriously affects the results of the Book, Lecture, and Experiment Method classes. This is

TABLE XIII A[1]

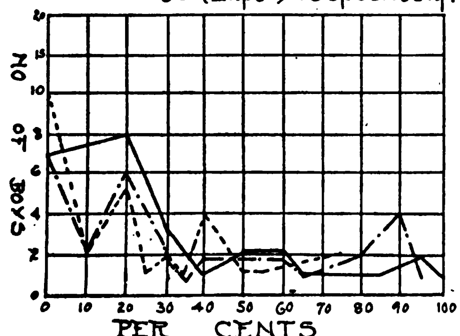
THE CONDENSER - 21 DAY TEST

The Book, Lecture, and Experiment Methods Compared

METHOD	CLASS	NO. OF BOYS	DATE	TIME OF DAY	AV'GE TIME (MIN) LES	AV'GE TIME (MIN) EXAM	RESULT AVGE %	RESULT MAX %	RESULT MIN %	RESULT MEDIAN %	WEATHER	LIGHT	AIR IN ROOM	TEMPERATURE	HUMIDITY	PREVIOUS HOURS	I No	I %	II No	II %	III No	III %	IV No	IV %	V No	V %
Book	$8B^3$	29	4/5/11	10:00	–	14	23	75	0	0	M	G	G	67	62	Arith	10	34	7	24	7	24	2	7	11	38
Lecture	$8B^2$	28	4/5/11.	1:00	–	13	34	100	0	20	CR	G	G	68	64	5/1/11/4/0	18	64	8	29	9	32	6	21	11	39
Exper.	$8B^1$	33	4/5/11.	1:40	–	11	37	95	0	30	CL	G	G	67	64	11/10/2 1/0/6	20	61	17	52	11	33	11	33	12	36

CR·Clear; CL·Cloudy; M·Mist; G·Good; 1·Arith; 1·Arith Test; 2·Comp; 4·Geog; 5·Gram; 6·Hist; 6·Hist Test; 10·Phys Tr; 11·Read, o·Lunch

GRAPH XIII A' Shows the attainment of $8B^3$ (Book), $8B^2$ (Lecture), and $8B^1$ (Exper) respectively.



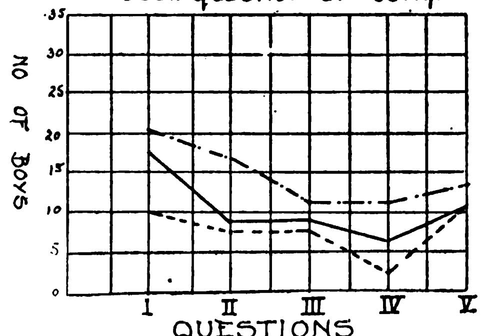
KEY

- - - - - - - Book

———— Lecture

–·—·– Exper.

Graph 13a' Shows the number of boys in each class, who answered each question correctly.



not in strict harmony with some of our preceding conclusions. But this is an exceptionally difficult lesson. Therefore, a fairer conclusion would be, "An interval of time (21 days) seriously affects the results of the Book, Lecture, and Experiment Method, *if the lesson is of exceptional difficulty.*"

2. In the order of their ability to retain original impressions the methods rank as follows: 1st, Experiment Method; 2nd, Lecture Method; 3rd, Book Method.

EXPERIMENT XIV-A

General Observations

This Experiment is like Experiment X-A. The aim here, as well as there, was to compare the general abilities of the three classes taught by the Book, Lecture and Experiment methods. In order to do this, a test covering in part the same field that the individual Experiments covered, was given April 25th, 1911. Save the time of day, the conditions in each of the methods was singularly the same. (See TABLE XIV-A) The time consumed in the test was not noted.

Notes

(a) Book Method:—The boys were surprised to get the mimeographed test-questions. They were urged to answer the questionnaire truthfully.

(b) Lecture Method:—Great importance was attached to the test on account of the mimeographed question-sheet and the scope of the quesionts.

(c) Experiment Method:—The boys took the test very seriously. Their class teacher came in and scolded them for a minute or two. Some stayed over into the next period in order to answer the questions.

The Test

The test (App. II, page 157) is composed of questions chosen from all of the previous 8B tests of this series. It consists of eight rather hard questions. Without exception, all of them are memory questions.

The Questionnaire

The questionnaire (App. II, page 157) is exactly the same as in Experiment X-A. It is interesting to see how these boys, all of whom expect to graduate within two months, answered the questions.

Discussion

The results show that the most efficient method of teaching elementary science is the Experiment Method. Next in order come the Lecture and Book methods. The averages for each method are: Experiment Method, 43%; Lecture Method, 35%; Book Method, 29%. The Book Method class is very bright. Yet their natural brightness was not sufficient to conquer defects in the method of instruction.

On the other hand, the superiority of the Experiment Method is brought out in spite of the natural dullness of the class. The probability is that the average per cent would be higher for the Experiment Method and lower for the Book Method if the classes were the same average intelligence.

In this Experiment, as in Experiment X-A, the Lecture Method is content with a median position between the Book and Experiment Methods.

Graph 14a and TABLE XIV-A show that the Experiment Method made its greatest gains in questions 4, 5, 6, and 7. These are questions that require a detailed knowledge of concrete facts and processes. It is evident that the Experiment Method, and the Experiment Method alone, furnished that knowledge. It is curious coincident that only three boys in each class answered question 1 correctly.

TABLE XIV A

SEMI-FINAL EXAMINATION

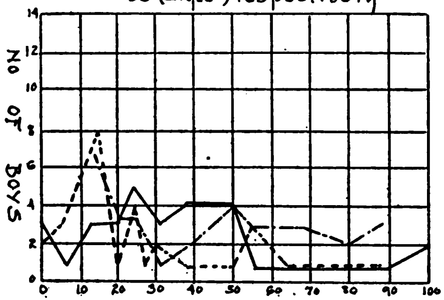
The Book, Lecture, and Experiment Methods Compared.

METHOD	CLASS	NO OF BOYS	DATE	TIME OF DAY	AVGE TIME (MIN) LES	AVGE TIME (MIN) EXAM	RESULT AVGE %	RESULT MAX %	RESULT MIN %	RESULT MEDIAN %	WEATHER	LIGHT	AIR IN ROOM	TEMPERATURE	HUMIDITY	PREVIOUS HOURS	I No	I %	II No	II %	III No	III %	IV No	IV %	V No	V %	VI No	VI %	VII No	VII %	VIII No	VIII %
BOOK	$8B^3$	30	4/25/11.	11:20	–	–	29	88	0	25	CR	G	G	70	63	1/4/3	3	10	25	83	12	40	5	17	4	13	5	17	10	33	13	43
LECTURE	$8B^2$	31	4/25/11.	1:40	–	–	35	100	0	31	CR	G	G	71	63	10/1/4 14/0/3	3	10	24	77	23	74	12	39	4	13	8	26	10	32	12	39
EXPER	$8B^1$	31	4/25/11.	1:00	–	–	43	88	13	38	CR	G	G	70	63	5/13/1/6/0	3	10	23	74	22	71	12	39	11	35	15	48	15	48	15	48

No and % Correct per Question.

CR: Clear; G: Good; 1: Arith; 3: Draw; 4: Geog; 5: Gram; 6: Hist; 10: Phys Tr; 13: Spell; 14: Study; 0: Lunch hour.

GRAPH XIV A Shows the attainment of $8B^3$ (Book), $8B^2$ (Lecture), and $8B^1$ (Exper) respectively



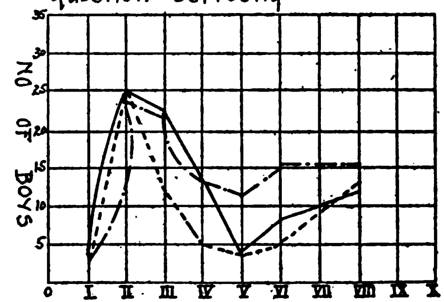
KEY

- - - - - - - BOOK

——————— LECTURE

—·—·— EXPER.

Graph 14a Shows the number of boys in each class, who answered each question correctly



This test, like the similar one in Experiment X-A, offers a good opportunity to study the effects of time on original impressions. In order to do this we will tabulate the absolute and per cental numbers of correct answers for each question.[1]

Question	Original test		Interval ‡	First repetition		Interval ‡	Present test		Method
	No.*	%†		No.*	%†		No.*	%†	
1.	9	28	....	......	......	55 da	3	10	Book
	10	36	....	......	......	55 da	3	10	Lecture
	22	71	....	......	......	55 da	3	10	Expt.
2.	30	94	....	......	......	55 da	25	83	Book
	25	89	....	......	......	55 da	24	77	Lecture
	30	97	....	......	......	55 da	23	74	Expt.
3.	23	65	14 da	13	42	44 da	12	40	Book
	26	91	14 da	17	64	44 da	23	74	Lecture
	28	86	14 da	15	48	44 da	22	71	Expt.
4.	28	85	21 da	7	24	41 da	5	17	Book
	23	79	21 da	8	29	41 da	12	39	Lecture
	24	73	21 da	17	52	41 da	12	39	Expt.
5.	15	45	21 da	2	7	41 da	4	13	Book
	13	45	21 da	6	21	41 da	4	13	Lecture
	14	43	21 da	11	33	41 da	11	35	Expt.
6.	15	45	6 da	12	37	48 da	5	17	Book
	19	65	6 da	14	54	48 da	8	26	Lecture
	21	61	6 da	17	55	48 da	15	48	Expt.
7.	26	79	21 da	7	24	41 da	10	33	Book
	23	79	21 da	9	32	41 da	10	32	Lecture
	27	82	21 da	11	33	41 da	15	48	Expt.
8.	16	48	21 da	11	38	41 da	13	43	Book
	11	38	21 da	11	39	41 da	12	39	Lecture
	13	39	21 da	12	36	41 da	15	48	Expt.

1. Because question 3 consists of two questions from two different tests, the figures for all items in both questions are added together and divided by two. The quotient is taken as the figure for question 3.

* Number of boys who answered correctly.

† Per cent of boys who answered correctly.

‡ Since the original test.

In Experiment X-A the statement was made that the longer the interval between the original lesson and the test, the less is the power of retention. If we test after an interval of five days, and then test again after an interval of five years, it is safe to say that the power of retention will be much less, if not entirely lost, at the end of the second interval. But in Experiment X-A, the greatest interval was 56 days, and within that limit it was found that the power of retention varies inversely as the length of time.

In this Experiment, disregarding the nature of the questions, the subject-matter, etc., we find decreases in the absolute and per cental number of correct answers in all intervals except one. We may say, then, that the permanency of retention is lessened, or weakened by time. The question arises: To what extent, proportion, or degree, is it weakend? This question is very important. The answer to it is even more important. But we look for it in vain in this Experiment. This statement is borne out by the following figures:

Questions	*Loss: First repetition 6-21 days after lesson*		*Loss: Second repetition 41-55 days after lesson*	
	Absolute	*Per cent.*	*Absolute*	*Per cent.*
3	32	124	20	81
4	43	168	46	180
5	23	163	23	163
6	12	65	27	154
7	49	193	41	164
8	6	39	3	19
Total	165	752	160	761

In individual questions, the sets of figures, for both repetitions contradict each other as often as not. In the total, we note 165 asbolute and 752 per cental losses for the first repetition, and 160 absolute and 761 per cental losses for the second repetition. The absolute loss in the first repetition is slightly greater than in the second; whereas the per cental loss is slightly smaller.

If we judge on the basis of absolute losses, we are justified in concluding that the power of retention varies directly as the

length of the time between the original lesson and the test. If we judge on a per cental basis, which is more equitable, the conclusion of Experiment X-A, that the power of retention varies inversely as the length of time, is confirmed. It will be observed, however, that both of these conclusions are drawn on a very narrow margin. Whereas the conclusion in Experiment X-A is based on good, substantial figures. If we say that this Experiment neither confirms nor denies the conclusion that the power of retention varies inversely as the length of time between the original lesson and the test, we settle the matter justly. In the absence of further experimentation the first conclusion must stand.

Let us now try to discover how time affects the three different methods of instruction. Since we have two repetitions for each question (except 1 and 2), we will give the figures for each method in the two repetitions:

BOOK METHOD

(First Repetition—6 to 21 days after lesson)

Questions	*Absolute number of correct answers*		*Absolute loss*	*Per cent. loss*
	Original test	*Interval test*		
3	23	13	10	43
4	28	7	21	75
5	15	2	13	87
6	15	12	3	20
7	26	7	19	73
8	16	11	5	31
Total....................................			71	329

(Second Repetition—41 to 55 days after lesson)

Questions	*Absolute number of correct answers*		*Absolute loss*	*Per cent. loss*
	Original test	*Interval test*		
3	23	12	11	48
4	28	5	23	82
5	15	4	11	73
6	15	5	10	67
7	26	10	16	62
8	16	13	3	19
Total....................................			74	351

Total ABSOLUTE LOSS in BOTH Interval Tests.................. 145
Total PER CENTAL LOSS in BOTH Interval Tests............ 680

LECTURE METHOD

(First Repetition—6 to 21 days after lesson)

Questions	Absolute number of correct answers		Absolute loss	Per cent. loss
	Original test	Interval test		
3	26	17	9	35
4	23	8	15	65
5	13	6	7	54
6	19	14	5	26
7	23	9	14	61
8	11	11	0	0
Total......................................			50	241

(Second Repetition—41 to 55 days after lesson)

Questions	Absolute number of correct answers		Absolute loss	Per cent. loss
	Original test	Interval test		
3	26	23	3	11
4	23	12	11	48
5	13	4	9	69
6	19	8	11	58
7	23	10	13	57
8	11	12	..*	..*
Total......................................			47	243

* Gain.

Total ABSOLUTE LOSS in BOTH Repititions.................... 97

Total PER CENTAL LOSS in BOTH Repetitions................ 484

EXPERIMENT METHOD

(First Repetition—6 to 21 days after lesson)

Questions	Absolute number of correct answers		Absolute loss	Per cent. loss
	Original test	Interval test		
3	28	15	13	46
4	24	17	7	28
5	14	11	3	22
6	21	17	4	19
7	27	11	16	59
8	13	12	1	8
Total......................................			44	182

(Second Repetition—41 to 55 days after lesson)

Questions	Absolute number of correct answers		Absolute loss	Per cent. loss
	Original test	Interval test		
3	28	22	6	22
4	24	12	12	50
5	14	11	3	21
6	21	15	6	29
7	27	15	12	45
8	13	15	..*	..*
Total....................................			39	167

* Gain.

Total ABSOLUTE LOSS in BOTH Repetitions.................. 83
Total PER CENTAL LOSS in BOTH Repetions................. 349

TOTAL ABSOLUTE LOSS OF THE BOOK METHOD.......... 145
TOTAL ABSOLUTE LOSS OF THE LECTURE METHOD...... 97
TOTAL ABSOLUTE LOSS OF THE EXPERIMENT METHOD 83
TOTAL PER CENTAL LOSS OF THE BOOK METHOD...... 680
TOTAL PER CENTAL LOSS OF THE LECTURE METHOD.. 484
TOTAL PER CENTAL LOSS OF THE EXPERIMENTAL METHOD 349

The figures show very clearly and definitely that the same interval of time reduces the power of retention in the Book Method *most;* in the Lecture Method, *less;* and in the Experiment Method, *least.*

Since that method which leaves the most permanent impression is considered the best, we must conclude that the Experiment Method is the best method of teaching elementary science.

As in Experiment X-A, the boys were given an opportunity to express themselves regarding the method of teaching. The questionnaire in both cases was the same, (see App. II, page 157.) Here, too, the vote and suggestions of each class are recorded.

BOOK METHOD CLASS

Experiment Method.. 15 votes
Combination Method.. 2 "
Lecture Method.. 2 "
Meangingless answers.. 1 "
No answer*.. 10 "

* Some boys had no opportunity to finish.

Specimen answers and suggestions:

"I like to be taught by experiment where I can see for myself."

"I like to be taught by the old method of your giving cards and performing the experiment." (Combination.)

"I like the method which allows to see the construction and operation of the experiment."

"I like to be taught by experimenting."

"I would like it better if the work were executed."

"I like to be taught by experiments and explanations from the teacher."

"I like to be taught by the way I was taught in 8A." (Combination.)

"I like to be taught by experimenting the work."

"I suggest that instead of sheets the teacher should lecture on the subject because we can always talk more convincingly than we can write. And on sheets we can not write much, having a scarcity of space."

"I like to be taught by the teacher explaining the experiment on his desk."

"I like to be taught by the method where you can see the experiment."

LECTURE METHOD CLASS

Experiment Method	11 votes
Combination Method	2 "
Lecture Method	4 "
Laboratory Method	1 "
Lecture—Experiment Method	7 "
Lecture-Book Method	1 "
Meaningless answers	2 "
No answers	3 "

Specimen answers and suggestions:

"I would like to be taught by the same method as usual." (Combination.)

"I like to be taught by the standing up around the desk and looking how you do it."

"I like to be taught by the following method, to be lectured on subject and shown how thing is formed and put to use."

"Would like to be taught by lectures and experiment in class."

"I like to be taught by the method of explaining the experiment in class and not giving any homework"

"I like to be taught by the talking method."

"I like to be taught by the boys gathering around the desk and the teacher working the experiment."

"I like to be taught that you should show the experiment but instead of we having to write the experiment in book you should make two sheets on one questions on other answers. I should like to draw the experiment."

"I like to be taught by the method that you talk to us and show it to us by apparatus."

"I like the method we have now."

"The method that I like to be taught is to lecture and show the works of the lecture."

"I would like to be taught by doing the experiment before us."

"I think that we should do our work every time in books so that when a test comes I should be able to study it over and be ready for the test; but the way Mr. Mayman explains us then on the second day we forget it and when a test comes we have nearly forgot everything we have learned."

"I like to be taught by going up by the desk. To see is to believe."

"I suggest that you tell certain boys to illustrate experiment. For example you tell me how to do something then I do it for the class."

"By having everything explained to me, a book to read from and diagram to study from."

"Science could not be carried out any better in any other school than the way it is here. There is only one suggestion that I could make and that is that we ought not draw any diagram to the experiment; writing would be sufficient."

"I would like to be taught by the teacher and not by the card. The note-books are of no use, because, after writing the experiment into the book we leave it alone, therefore forget it."

"I like to be taught by the method as I am now."

EXPERIMENT METHOD CLASS

Experiment Method	15	votes
Combination Method	4	"
Lecture Method	2	"
Experiment—Book Method	1	"
Experiment—Lecture Method	1	"
Meaningless answers	5	"
No answers	3	"

Specimen answers and suggestions:

"I like to be taught as I am."

"I like to be taught by the teacher doing one thing at a time."

"I like to be taught by experiment and the teacher explaining the experiment."

"I suggest that we do little homework as we have been doing and experiment more. This will make the work more interesting, clearer and easier to understand. If we do home-work we just scribble it off and make the diagram, get our mark and in the end we know nothing at all."

"I like to be taught by your method of doing this work."

"I would like to be taught by the method of explaining the science and the experiment and the diagram should be done in the book."

'I like to be taught by explanations and illustrations." (Lecture).

"The suggestions that I have to make is that the experiment be shown to the pupils but instead of the homework the pupil should be made to read on the subject of which he was shown."

"I like to be taught in the same manner as is taught now."

"I think you teach the science very plainly but I do not understand it."

"The method I like to be taught is last term's method." (Combination.)

"I like to be taught by experiments."

"This method of teaching is enough for pupils to understand the science work."

"I like the method as it is."

"I would like to be taught by our old method." (Combination.)

The total vote for each of the three methods is:

Experiment Method	41 votes
Lecture Method	8 "
Book Method	0 "

The majority vote for the Experiment Method is overwhelming. It is interesting to note that not one vote was cast for the Book Method.

In the Lecture Method class seven boys voted for a new combination of methods, i. e., Experiment-Lecture Method. This indicates that they like to be taught by the Experiment Method and yet not lose the benefits of clear explanation.

Partial Conclusions

1. The most efficient method of teaching elementary science is the Experiment Method.

2. The least efficient is the Book Method.

3. The Lecture Method is a fairly good method of teaching elementary science.

3. The effect of time is to reduce the permanency of original impressions regardless of the method of teaching or the material taught.

5. The impressions left by the Experiment Method are fairly permanent.

6. The impressions left by the Lecture Method are less permanent.

7. The impressions left by the Book Method are least permanent.

8. The detailed and concrete presentation of the Experiment Method is a great aid to memory.

9. The most popular method of instruction is the Experiment Method.

10. The least popular method of instruction is the Book Method.

SUMMARY

Following is a summary of the original experiments and not so much of the abridgement as given in this pamphlet. Reference to the tables and graphs summarizing the series, will make references to the original MS understandable.

This investigation was undertaken to obtain a basis for a judgment on the best method of teaching physics in the elementary school. Four methods were employed, the Lecture, the Book, the Experiment, and the Combination Methods. About 500 boys of the seventh and eighth years were so divided that each lesson in science was taught to each class of the same grade by a different method. Upon the completion of the series of lessons the classes were tested by uniform tests, and thus the effect of each method was noted. Some tests were given after a stated interval in order to ascertain how the impressions left by each of the methods were affected by time.

The series of experiments extended over the first and second school terms of 1911. During the second term many of the experiments of the first term were repeated for purposes of verification. Altogether there were 30 experiments. Only in five of these did the Combination Method figure. The average age was 13 years, 10 months. The total number of test papers rated was 3,453. To this number the Book Method classes contributed 1,114, the Lecture Method 1,072, the Experiment Method 1,094, and the Combination Method 173. In all about 18,500 individual questions were answered and rated.

The average per cents that the Book, Lecture, Experiment, and Combination Methods attained in each experiment are given in Table III, and graphically shown in Graph III. Adding the average per cent of each method, we have: Book 1555, Lecture 1891, Experiment 1949, Combination 268. On the basis of average per cent attainments, the Experiment Method produces the best results. The Lecture Method, a close second, is only 58 units lower, while the Book Method is far behind.

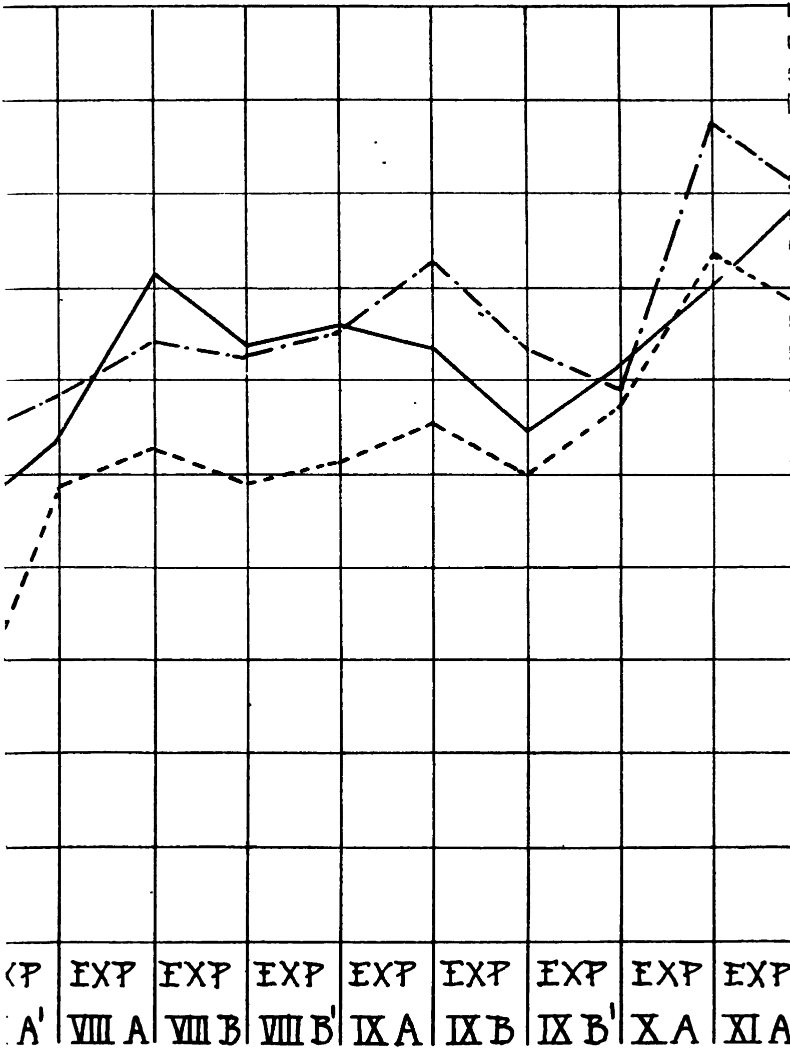
TABLE III.

THE AVERAGE PER CENT THAT THE BOOK, LECTURE, EXPERIMENT AND COMBINATION METHODS ATTAINED IN EACH EXPERIMENT.

METHOD	Exp. I A	Exp. I B	Exp. I A1	Exp. I B1	Exp. II A	Exp. III A	Exp. IV A	Exp. V A	Exp. VI A	Exp. VI B	Exp. VI A1	Exp. VI B1	Exp. VI B2	Exp. VII A	Exp. VII B	Exp. VII A1	Exp. VIII A	Exp. VIII B	Exp. VIII B1	Exp. IX A	Exp. IX B	Exp. IX B1	Exp. X A	Exp. XI A	Exp. XI B	Exp. XII A	Exp. XII A1	Exp. XIII A	Exp. XIII A1	Exp. XIV A	Exp. XV A	Total
BOOK	65	50	63	67	10	21	54	54	65	63	66	61	60	32	53	21	49	53	49	51	56	50	56	74	67	67	59	60	23	29		1555
LECTURE	74	72	74	76	48	65	68	70	75	66	72	71	63	62	59	45	53	71	62	66	63	53	61	70	79	61	58	65	34	35		1891
EXPERIMENT	84	77	88	74	43	30	42	54	73	82	72	80	79	58	74	54	59	63	62	66	74	64	59	88	79	78	59	61	37	43		1949
COMBINATION			75	66	45	32	50																									268

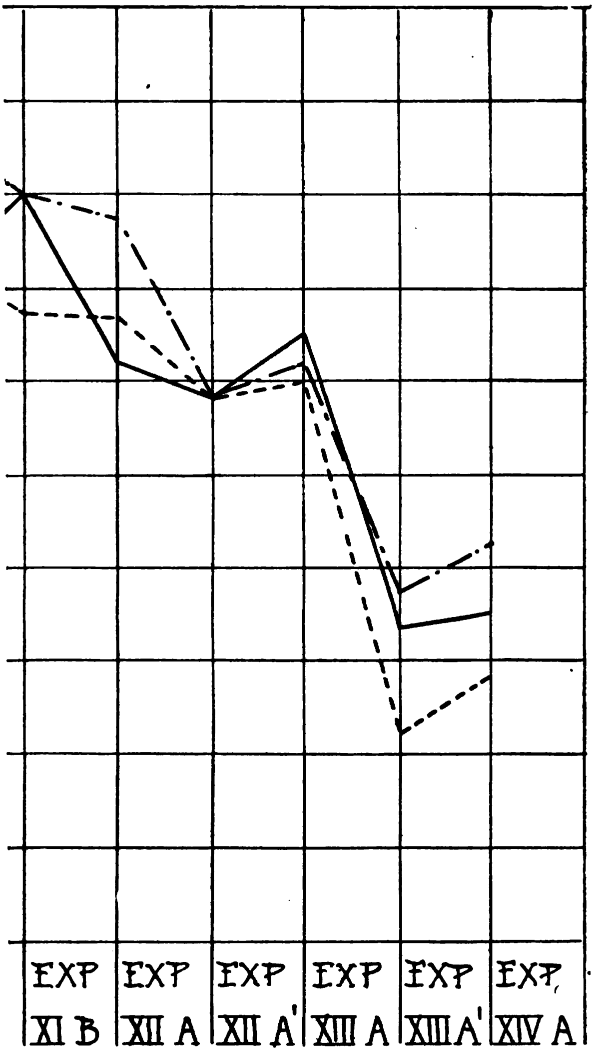
II

and Combination Methods att



re ; —·—·—·— Experiment; —···—···

ain in each Experiment.



·— Combination.

The Experiment Method produces the highest average per cents in 16 of the 30 experiments. In 4 of the experiments the average per cents were the same as in the Lecture Method. In only one experiment (IV-A) did it take third place. In two experiments (V-A, XII-A) it tied with the Book Method for second place. In the remaining seven experiments the Experiment Method takes second place.

The Lecture Method produces the highest average per cents in 10 of the 30 experiments. In four the per cents are the same as in the Experiment Method. In 13 experiments it takes second place. In three experiments it takes third place.

The Book Method did not produce the highest average per cent in any experiment. In one it tied with the Experiment Method for first place (XII-A1), in three it was distinctly second, and in one it tied for second with the Experiment Method. In the remaining 25 experiments it produced the lowest average per cents.

Eight of the 30 experiments are repetitions of the corresponding experiments of the term before. In the Experiment Method four first term conclusions are confirmed and four are not. In the Lecture Method three are confirmed and five are not. In the Book Method seven are confirmed and one is not. This indicates that the conclusions (as far as these eight experiments are concerned) regarding the Book Method are firmly established. The conclusions regarding the Experiment and Lecture Methods (as regards these eight experiments) are open to doubt. Further extended investigation might be profitably undertaken.

Twelve of the experiments are interval experiments, i. e., the test separated by a stated interval of time from the lesson. In eight of these the Experiment Method came out first; in two it tied with the Lecture Method, and in one with the Book Method for first place. In one Experiment it takes second place.

The Lecture Method attained first place in one of the 12 interval tests; in two it tied with the Experiment Method for first place. Seven times it attained second place, and twice third place.

The Book Method tied with the Experiment Method for first place once, and once it attained second place. In the remaining 10 experiments it was third.

This indicates that the impressions left by the Experiment method are the most permanent; those left by the Lecture Method less permanent; and those left by the Book Method least permanent. Experiments X-A, page 106 and XIV-A, page 123 alone sufficiently prove this.

In four of the five experiments where the Combination Method was included the average per cents of this fourth method were far below those of the Lecture Method. In two experiments its average per cents were much below those of the Experiment Method, and in two others its average attainment was about as good as that of the Experiment Method. Although we have only five experiments from which to draw our conclusions, the vaule of note-book work seems to be seriously impaired. Further experimentation in this direction is highly desirable.

Graph III shows that there is a very deep valley for the Experiment and Book Methods in Experiments II-A and III-A. This is explained by the children's inability to grasp quantitative work intelligently. The Lecture Method class did fairly well not because it showed superior ability, but because it imitated the process of working the problems.

In Table IV and Graph IV the Book, Lecture, and Experiment Methods are compared on the basis of median, maximum, and minimum per cents. The total median per cents for each method are: Experiment 2022, Lecture 1976, Book 1585. This in complete accord with the preceding comparison on the basis of average per cents.

The maximum total per cents of each method are: Lecture 2992, Experiment 2878, Book 2736. This shows a new order of relative efficiency. It is not so. The figures are not indicative of the facts. Maximum attainment in each class means highest score; but nothing shows the *number* of such highest scores in each class. In one class (X-A) there were as many as 19 perfect scores; but this is not shown either in the table or on the graph. The graphs of individual experiments will reveal the truth.

...in Methods attained in each Experiment.

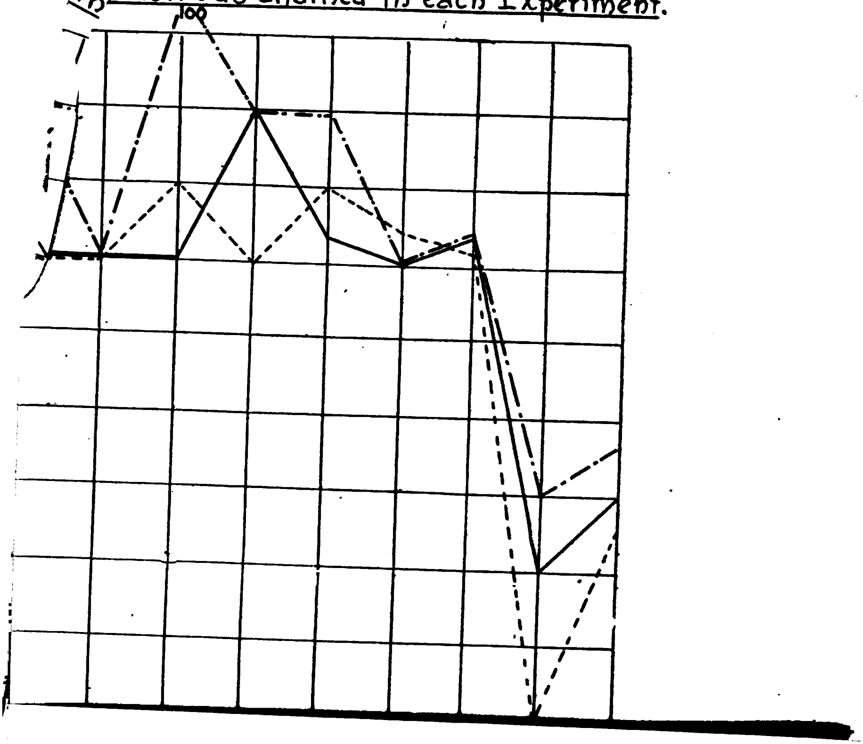


TABLE IV.

THE MEDIAN, MAXIMUM AND MINIMUM PER CENT THAT THE BOOK, LECTURE, EXPERIMENT AND COMBINATION METHODS ATTAINED IN EACH EXPERIMENT.

MEDIAN.

METHOD	Exp. I A	Exp. I B	Exp. I A¹	Exp. I B¹	Exp. II A	Exp. III A	Exp. IV A	Exp. V A	Exp. VI A	Exp. VI B	Exp. VI A¹	Exp. VI B¹	Exp. VI B²	Exp. VII A	Exp. VII B	Exp. VII A¹	Exp. VIII A	Exp. VIII B	Exp. VIII B¹	Exp. IX A	Exp. IX B	Exp. IX B¹	Exp. X A	Exp. XI A	Exp. XI B	Exp. XII A	Exp. XII A¹	Exp. XIII A	Exp. XIII A¹	Exp. XIV A	Exp. XV A	Total
BOOK	80	60	60	80	0	12	56	60	70	70	70	60	70	25	50	25	44	52	48	60	60	60	58	70	60	70	65	65	0	25		1585
LECTURE	80	80	80	80	60	60	70	80	80	70	80	80	60	62	75	50	64	74	60	60	70	60	60	60	80	65	60	65	20	31		1976
EXPERIMENT	80	80	80	80	40	32	40	60	75	90	80	90	80	75	75	50	56	56	60	80	80	80	60	100	80	80	60	65	30	38		2022
COMBINATION			80	60	50	36	49																									
MAXIMUM.																																
BOOK	100	100	100	100	60	92	100	100	100	100	100	100	100	75	100	75	88	85	80	80	80	80	81	100	100	100	95	100	75	88		2736
LECTURE	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	96	100	100	100	100	100	96	100	100	100	100	100	100	100		2992
EXPERIMENT	100	100	100	100	80	60	94	100	100	100	90	100	100	100	100	100	78	100	100	100	100	100	98	100	100	100	95	100	95	88		2878
COMBINATION			100	100	80	60	93																									
MINIMUM.																																
BOOK	0	0	0	20	0	0	0	0	0	0	10	0	0	0	0	0	0	17	17	20	0	0	29	40	0	0	0	20	0	0		173
LECTURE	20	20	40	40	0	8	27	20	20	0	0	0	0	0	0	0	20	32	14	0	20	0	31	0	0	40	0	15	0	0		369
EXPERIMENT	60	20	40	0	0	0	0	0	20	10	40	10	40	0	25	0	20	34	40	20	20	20	17	20	40	40	30	0	0	13		579
COMBINATION			20	0	0	0	12																									

While the results for the minimum per cents have the same general fault, it is not so extreme and therefore less misleading. The number of zero scores in each class is not large. The total minimum per cents in each method are: Experiment 579, Lecture 369, Book 173. This is in accord with the average and median totals.

In Table V and in Graph V is shown the relative amount of time consumed in the actual teaching of each lesson. The total time consumed by each method is: Lecture Method, 121 minutes; Experiment Method, 143 minutes; Book Method, 232 minutes. This would mean that the Book Method is very wasteful of time; the Experiment Method less so, and the Lecture Method least so. Graph V shows no great deviation between the three curves for the greater part. An undue proportion of the total time in the Book Method comes from experiments involving quantitative work, to which three full periods were allowed. Excluding the exceptional cases, we find that, as far as the actual teaching of a lesson is concerned, the time consumed by each method is about the same. This leaves out of consideration the time spent by the teacher in preparing lessons. From the teacher's point of view, the methods in the order of least time consumption are: 1st, Book Method; 2d, Lecture Method; 3d, Experiment Method.

"Interest is the mother of attention." Without interest there is no attention and without attention intelligent work cannot be done. The Book Method of teaching elementary science did not prove interesting to the boys. Only in rare cases was curiosity aroused on account of the novelty of the method.

On the other hand, the Lecture Method proved to be most interesting. It seems that the element of personality is the important feature of this method. Not one case is recorded where this method failed to arouse and hold the attention. In experiments where the work was largely quantitative (II-A) in nature the Lecture Method far excelled the other two. This was largely due to the ease of grasping clear explanations. The boys were not aroused to superior thinking, but merely remembered and imitated the explanations given them.

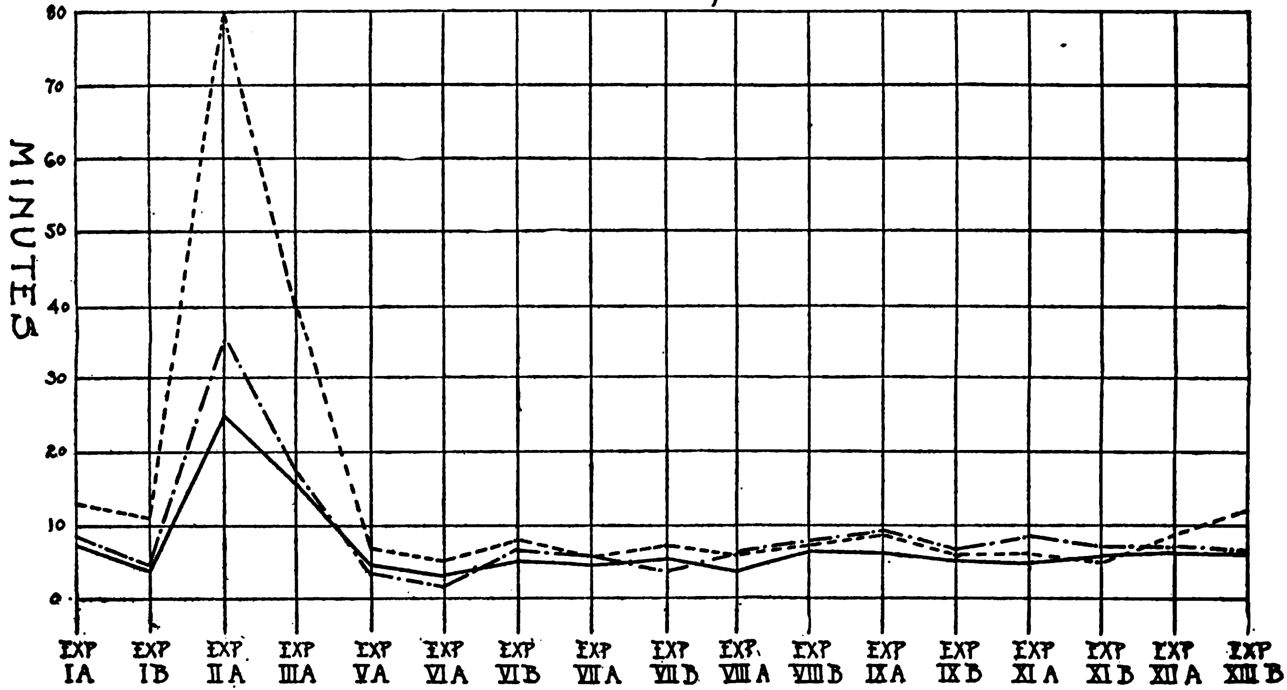
TABLE V.

THE AVERAGE NUMBER OF MINUTES THE BOOK, LECTURE, EXPERIMENT AND COMBINATION METHODS CONSUMED IN THE TEACHING OF THE SAME LESSON IN EACH EXPERIMENT.

METHOD	Exp. I A	Exp. I B	Exp. I A^1	Exp. I B^1	Exp. II A	Exp. III A	Exp. IV A	Exp. V A	Exp. VI A	Exp. VI B	Exp. VI A^1	Exp. VI B^1	Exp. VI B^2	Exp. VII A	Exp. VII B	Exp. VII A^1	Exp. VIII A	Exp. VIII B	Exp. VIII B^1	Exp. IX A	Exp. IX B	Exp. IX B^1	Exp. X A	Exp. XI A	Exp. XI B	Exp. XII A	Exp. XII A^1	Exp. XIII A	Exp. XIII A^1	Exp. XIV A	Exp. XV A	Total
BOOK	13	11	—	—	80	40	—	7	5	8	—	—	—	6	7	—	6	7	—	8	5	—	—	5	4	9	—	11	—	—		232
LECTURE	8	5	—	—	25	16	—	5	4	5	—	—	—	5	5	—	4	7	—	6	5	—	—	4	5	6	—	6	—	—		121
EXPERIMENT	9	5	—	—	35	18	—	4	3	6	—	—	—	6	4	—	6	7	—	8	5	—	—	8	6	7	—	6	—	—		143
COMBINATION			—	—	60	40	—																									

GRAPH V

The average number of minutes the Book, Lecture, and Experiment Methods consumed in the teaching of the same lesson.



Note:- - - - - - - - - Book; ———— Lecture; —·—·—·— Experiment.

It is hard to say whether or not the Experiment Method was as interesting as the Lecture Method to the boys. Certain it is that in the Lecture Method attention and interest were directed to the essentials of each lesson, while in the Experiment Method such interest and attention were necessarily divided between the lesson, itself, and the apparatus that was used.

Of the three methods, the Book Method was the most fatiguing. Mind-wandering, yawning, staring, stretching, inattention and listlessness were invariably noted. The Lecture and Experiment Methods had about an equal share in reducing fatigue to a minimum.

It was demonstrated, again and again, that not only are boys of elementary school age unable to get the thought by means of symbols from the printed page, but that even simple diagrams did not prove of much benefit. If the pupils remembered anything, they remembered words, and not ideas. In several cases a simple diagram was reproduced without the slightest conception of its significance. On the other hand, the concrete and detailed presentation in the Experiment Method proved of great aid in reproduction. In other words, concrete memory images were reproduced more readily than verbal or auditory memory images.

The Book Method failed to produce good results either in thought or in memory work. It cannot be said, however, that the Experiment Method and Lecture Method were particularly successful in arousing the boys to original thought. Judging from the character of the answers that were given by the classes, it is safe to say that the Book Method class depended too much upon memory. If the exact statement of the book was forgotten, the answer was usually incorrect. There was no attempt to reach an answer through a process of sound reasoning. The ingenious "inventions" that the Book Method class frequently resorted to are not indications of sound reasoning. On the other hand, the Lecture and Experiment Method classes, especially the latter, showed more power of independent thought and self-reliance.

FINAL CONCLUSIONS

1. On the basis of efficiency as measured by *percental attainments,* by *lasting impressions* on the minds of elementary school pupils, by *persistence in memory,* by *encouragement of independent thought and self-reliance,* and by *popularity among the pupils* the three methods rank as follows: First, Experiment Method; second, Lecture Method; third, Book Method.

2. On the basis of minimal time consumption in the actual teaching of the lessons, of arousing and holding interest and attention, and of the minimal expenditure of mental and physical energy they rank as follows: First, Lecture Method; second, Experimental Method; third, Book Method.

3. On the basis of minimal time consumption by the teacher in the preparation of the lessons, they rank: First, Book Method; second, Lecture Method; third, Experiment Method.

4. The amount retained in thought work, as well as in memory work, in elementary science is inversely proportional to the length of time elapsing between the presentation and the test.

5. No particular hour of the day or position in the general program need be reserved for elementary science.

6. Carefully written note-book work and neatly-drawn diagrams of science apparatus do not increase the pupils' knowledge of elementary science.

7. The work in elementary science must be concrete, and must be based on the daily experiences and observations of the pupil.

8. Elementary science in elementary schools should be largely, if not entirely, qualitative, and not quantitative.

9. As regards elementary science, elementary school pupils cannot get the thought from the printed page. Simple diagrams are of no material aid.

10. The Book Method of teaching elementary science might be used with fairly good results, provided the class is exceptionally bright.

11. Pupils who are taught by the Book Method show superior ability in the power of expression, and in the spelling of new scientific terms, as well as of familiar old terms.

12. The Combination Method consumes more time than the Experiment, Lecture, or Book Method, but does not produce better results.

13. Since the Experiment and Lecture Methods approach each other in so many respects, either one may be profitably used. Each produces good results. An ideal method might result from a combination of the two.

The time of day, weather, and temperature conditions, etc., are important factors in the teaching of any lesson. Because the method of teaching was not constant, these factors could not be evaluated. Since both the method of teaching and the weather and time conditions were variable factors conclusions about the relation between the two cannot be drawn. In several cases, however, the distracting effect of high wind was noted. In two cases low temperature and bad weather were thought responsible for poor work. On the whole the time of day, previous mental work, weather, and temperature conditions, did not affect the work one way or the other.

The value of repetition and extended periods of study are illustrated in experiments II-A, III-A, and IV-A. In the first, the average in the Book Method was 10%. In the second it was 21% and in the third it increased to 54%.

It was brought out (VII-A) that the use of books in connection with science work helps the children in the power of expression. Similarly, the wholesome effect of books upon correct spelling of scientific terms was noted (XIII-A).

That the Book Method of teaching elementary science might be used with a fair degree of success with bright children was demonstrated by three experiments (XI-A, XII-A, XII-A1).

That poor experimental demonstration, no matter how plausible the excuse, is detrimental to efficient teaching is shown by experiment XI-B.

That the teacher's judgment regarding a class with which he is familiar is usually correct is made plain by experiment XV-A.

The vote of the eighth-year boys showed that the Experiment Method was by far the most popular, receiving a total of 88 votes. The next in popularity was the Lecture Method, 23 votes, while the Book Method received only 11 votes.

APPENDIXES

APPENDIX I

Material for Book Method Classes

THE PENDULUM

If a plumb line is pulled out of the vertical direction, the attraction of gravity pulls it back toward the vertical. But the force it acquires in the falling causes the pendulum to swing beyond the vertical until it is stopped by the resistance of the air and the contrary pull of gravity. This latter forse starts again in the opposite direction to repeat its swing until it stops.

The pendulum with which we are familiar is the clock pendulum. Clock pendulums are made of many different kinds of material: wood, iron, brass, glass, etc. If we should replace our brass pendulum with a wooden or cork one of the same length we would find no difference in the time-keeping quality of our clock. Many experiments with pendulums of the same length, but of different materials and mass have established the following law:

The rate of vibration of a pendulum is independent of its material and mass.

But if we should make our pendulum longer or shorter we would very soon notice a difference in the time-keeping quality of our clock. Our clock would be too slow if the pendulum were made longer; and too fast if it were made shorter. Here, too, many experiments have established a rule or a law:

The rate of vibration of a pendulum is dependent upon its length.

Combining the two laws, we have:

The rate of vibration of a pendulum is independent of its material and mass; but dependent upon its length.

THE LEVER (First Class)

Balances swing back and forth somewhat as a pendulum does. The most important consideration is that the center of gravity of the system should be below the point of support. In the balance represented in Fig. I, the point of support is at *F*, and the center of gravity, when the weights are in the scale pans, is at *C* in the pointer. The position of *C* varies up and down with the load in scale pans. If the points of support *A* and *B*, for the scale pans are equally distant from *F*, we find that equal weights in the two pans will balance one another; but if the arms of the balance are unequal, the longer arm will require the lighter weight. For weighing small masses as the grocer does there is no

inconvenience in having iron weights enough to balance the articles weighed; but in weighing large things like loads of hay or coal, it is neces-

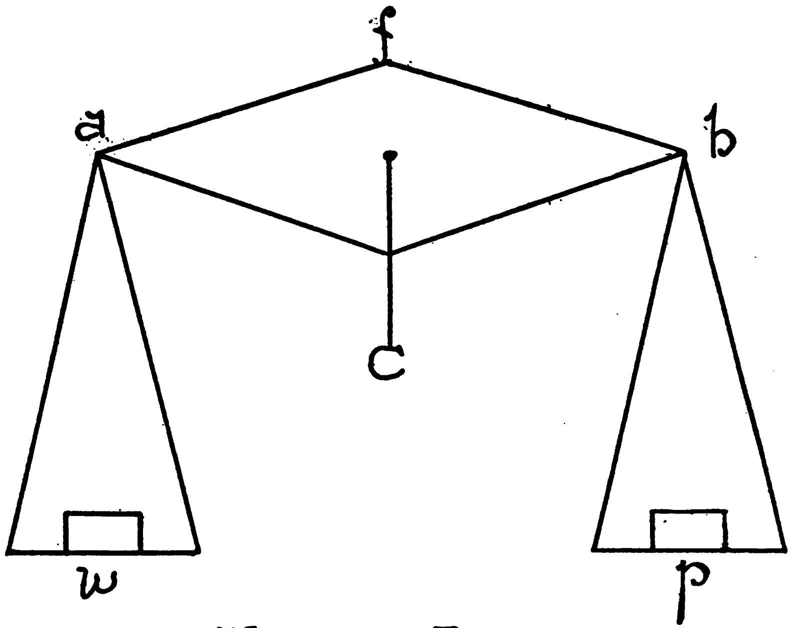


Figure I

sary to have some device for making a comparatively small amount of iron balance the large mass to be weighed. This is done by lengthening the arm of the balance upon which the iron weight is hung. We find that if we make the arm *BF* twice as long as *AF*, the weight *P* will balance twice its own weight at *W*. If the arm *BF* is made three times that of *AF*, *P* will balance three times its own weight at *W*. To make one pound balance twenty pounds it is necessary to give it an arm twenty times as long as the other. This is the principle upon which we construct steel-yards, hay scales, and platform scales.

This is also the principle which a man uses when he wishes to move a heavy rock with a crowbar. In Fig. II, *W* represents a heavy rock, *AB* the crowbar, another rock *F* is crowded under the bar close to *A*. The man applies his weight to the bar at *P* and because he uses the longer arm *BF*, his weight though very much less than that of the rock, may balance or even lift it. If *BF* is twenty times as long as *AF*, a downward pressure of

a hundred pounds at *B* will cause an upward pressure of 2000 pounds at the point *A*. Another name for the crowbar is *lever*. The rock *W*, is called the

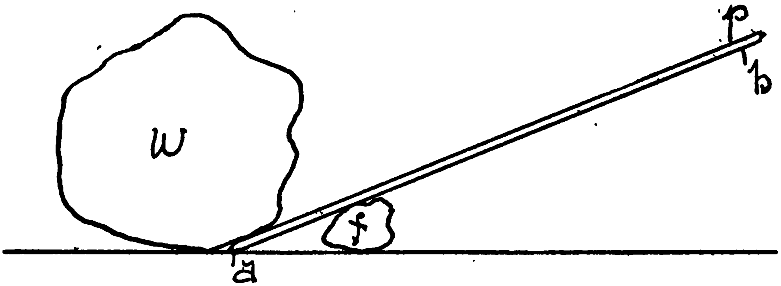


Figure II

weight, the rock *F*, the *fulcrum;* and, inasmuch as we propose to develop from this instrument ideas concerning more complex machines, where steam, wind or horse power may be applied at *P* instead of the weight of a man, it will be convenient to use the general term POWER for that. A leven in which the FULCRUM is between the POWER and the WEIGHT is called a lever of the first class.

If we study, once more, the example of the crowbar and the heavy rock we discover the following:

The product of power multiplied by power arm equals the product of weight multiplied by weight arm. If P=5 lbs., the distance between P and F (PD)=20 in., W=50 lbs., and the distance between W and F (WD) is 2 in., we have, according to the rule,

$$P \times PD = W \times WD$$
$$5 \times 20 = 50 \times 2$$

Illustrations of the lever of the first class are found in the claw-hammer, crow-bar, scissors, see-saw, beam balance, and steelyard.

SOUND

To-day we want to study tones produced by vibrating strings. In order that the string may do its best, we'll imagine it stretched across the top of a box. When the stretched string is plucked with the finger or bowed with a violin bow, it produces a certain sound. Now if we tighten the string somewhat and repeat the plucking or bowing, we notice that the pitch of the tone becomes higher. If we tighten it more and more, the pitch becomes higher and higher. We observe, then, that the tighter the string the higher is the pitch of tone.

Again we pluck our string in order to fix in our minds the pitch of the tone it produces. But if we shorteen this same string, by allowing only part of it to vibrate, just as the player shortens his violin strings by moving his fingers, we find that the pitch of the tone is higher. If the shortening is continued the pitch becomes higher and higher.

Knowing the pitch of the tone produced by the string we measure its length and replace it by one of the same length, but thicker or stouter. When this second string is plucked, although it is of the same length and is stretched just as tightly as the first, the pitch of the tone is lower. Many experiments in this line prove that the stouter or thicker the string is (although of the same length and tension) the lower the pitch of the tone produced.

All of this may be summarized by saying:

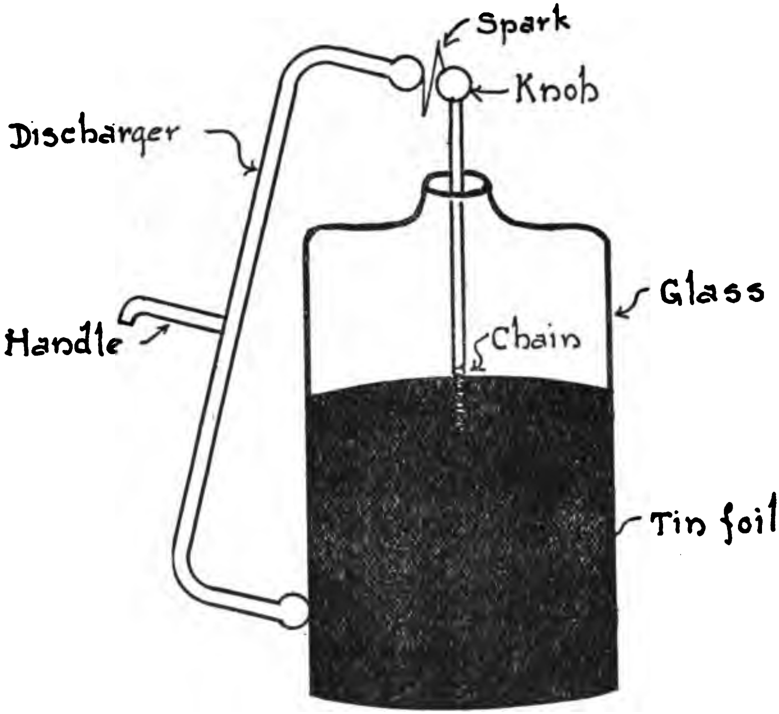
1. The tighter the string the higher the pitch of the tone.
2. The shorter the string the higher the pitch of the tone.
3. The thicker the string the lower the pitch of the tone.

ELECTRICITY (Condensers)

The principle of induction that we learned in connection with the electrophorus, is used to give a body a much greater charge than it would otherwise receive. To prove this we do the following: A piece of tin foil or ordinary tin (a cover from a shoe-blacking box will do) is placed on a larger pane of glass. After charging the electrophorus count the number of sparks that can be made to pass between the brass disk and the tin on the plate of glass. Discharge the tin by touching it. Lift the glass plate and place underneath it a piece of tin or tin-foil similar to the one that was placed on top of it. Connect it to the earth by touching it with the hand or connecting it to a gas or water pipe. If sparks from the electrophorus are made to pass now into the tin we find that it is capable of receiving a good many of them. That is, the sparks are stored up in this condenser which consists of nothing else than two conductors and a non-conductor (glass) between. If the upper and lower tins are touched at the same time a shock is felt. That is, the stored up electricity passes into the body. Sometimes this shock is heavy enough to cause severe pain. To avoid this we use a discharger or a bent metal rod which touches the two tins at the same time.

The *Leyden Jar* is a convenient form of condenser. It consists of a glass jar with a wooden stopper, through which passes a brass rod terminating outside in a metal ball and inside in a chain touching the inner coating of the jar. The jar is coated both outside and inside, to about 2/3 its height with tin-foil pasted on the glass. The Leyden Jar is

charged by holding it in the hand, or in some other way connecting the outer coating with the earth, and presenting the ball to some source of



electricity (an electrophorus for instance). It is discharged by touching the outside coating with one end of a discharger and bringing the other end near the knob of the jar, when the discharge will take place in the form of a heavy spark.

APPENDIX II

Tests

SCIENCE TEST — PENDULUM — GRADE 7A

1. Why does a pendulum keep on swinging when once started?
2. How would our clock be affected if the brass pendulum were replaced by one made of cork of the same length?
3. I have two pendulums of the same length, one made of wood and the other made of lead. The wooden one swings forty times a minute. How many times does the other one swing in the same time? Why?
4. Which will make more swings in a minute, a fifteen inch or a fifty inch pendulum?
5. If the clock is fast how will you adjust the pendulum? Why? If the clock is slow how will you adjust the pendulum? Why?

LEVER (First Class)

SCIENCE TEST — GRADE 7A

1. What is the relative position of fulcrum, weight and power in the lever of the first class?
2. Why are the following things illustrations of the lever of the first class? Scissors, see-saw, claw hammer.
3. State the law of the lever. Why do we call it a law?
4. Using a crowbar, 5 ft. long, a man wants to raise a boulder, 400 lbs. in weight. If he places his fulcrum one foot from the load, how much power will he have to use?
5. In weighing heavy loads, coal for instance, why does a small piece of iron, weighing about two pounds, balance one or more tons of coal?

VIBRATING STRINGS

SCIENCE TEST — GRADE 8A

1. Two strings are of the same thickness and both are stretched alike, but one is longer than the other. If sounded, how will they differ?
2. Two strings are of the same length and thickness, but when both are sounded one produces a tone of higher pitch. Why?
3. Two strings of the same length, and stretched to the same tension, produce tones of different pitch when sounded. What is the cause of lower pitch?

4. What three things affect the pitch of tones produced by vibrating strings?

5. In what two ways may a violinist produce tones of different pitch on the same string? Which is the better and easier way?

SEMI-FINAL TEST

8A CLASSES — April 27, 1911

I. Name the six sources from which we get heat.

II. What is the effect of heat on solids?

III. Brooklyn Bridge is 3 inches longer in summer than in winter. Explain this.

IV. What controls the temperature in our room? How is this done?

V. What is resonance?

VI. What is the effect of the body of the violin on the sounds produced by its vibrating strings?

VII. Two strings, of the same thickness and length, are stretched alike; but one is longer than the other. If sounded, in what will they differ?

VIII. What 3 things affect the pitch of tones, produced by vibrating strings?

1. **What is your opinion of this test?**
2. **Is it easy? Why? Is it hard? Why?**
3. **Do you like the work? Why?**
4. **Do you *not* like the work? Why**
5. **What suggestions do you make? (Write out suggestions plainly, honestly and fearlessly.)**
6. **By what method do you like to be taught?**

THE CONDENSER

SCIENCE TEST — GRADE 8B

1. What is a condenser? For what is it used?
2. Tell how a simple condenser may be made.
3. Give a full description of a Leyden Jar.
4. Tell how a condenser is charged.
5. How is a Leyden Jar or other condenser discharged? Why is a discharger used?

SEMI-FINAL TEST—PART I

8B CLASSES April 25, 1911

I. Describe how positive electricity may be produced by friction.

II. State the laws of mutual attraction and repulsion in electricity.

III. (a) What is an electrophorus?
(b) What is a condenser? For what is it used?

IV. Tell how a simple condenser may be made.

V. How is a condenser charged?

VI. Tell how the disk of an electrophorus is charged?

VII. Give a full description of a Leyden jar.

VIII. How is a Leyden jar, or any other condenser, discharged? Why is a discharger used?

1. What is your opinion of this test?
2. Is it easy? Why? Is it hard? Why?
3. Do you like the work? Why?
4. Do you *not* like the work? Why
5. What suggestions do you make? (Write out suggestions plainly, honestly and fearlessly.)
6. By what method do you like to be taught?

APPENDIX III

SCIENCE CARDS*

EXP. NO. THE PENDULUM (MASS) 7A

Obj.:—To find if the rate of vibration of a pendulum is changed by its material and mass.

App.:—Pendulums of wood, copper, brass, lead, support.

Oper.:—Adjust the pendulums so that each will have the same length. Start them swinging together.

Result:—Are the pendulums of the same material and weight? Do they have the same rate of vibration? Is the rate of vibration of a pendulum affected by its material and mass?

EXP. NO. THE PENDULUM (LENGTH) 7A

Obj.:—To find the relation between the length of a pendulum and its rate of vibration.

App.:—Pendulum, watch, meter stick, support.

Oper.:—Swing successively four pendulums of 5, 20, 45, and 80 cm long respectively. Count the number of vibrations of each in 30 seconds. Repeat three times and take the average.

Result:—What effect has the length of a pendulum on the rate of its vibration? If clock is fast how will you adjust the pendulum? If slow?

EXP. NO. THE LEVER (FIRST CLASS) 7A

Obj.:—To verify the law of the lever (First class).

App.:—Meter stick weights, string, support.

Oper.:—Balance the meter stick by means of a string. Attach a weight, 10 cm to the right of the fulcrum (point of support) and an equal weight to the left of the fulcrum at such distance that the meter stick will again balance. Note this distance.

Repeat with first weight at 10 cm from the fulcrum and note where a weight twice as heavy must be placed in order to restore the balance again. Make several trials, using different weights and distances, and noting in each case the weight W, its distance from the fulcrum WD, the power (= other weight) P, and its distance from the fulcrum PD. Find the products P times PD and W times WD.

Result:—State the law of the lever. What are the relative positions of fulcrum, weight, and power in the lever of the first class?

Illustrations:—Crow-bar, shovel, claw hammer, see-saw, steelyard.

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* The substance for these cards, as well as the form, is taken from "Graded Lessons in Elementary Science" Book I, by Hugo Newman—Ginn & Co.

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